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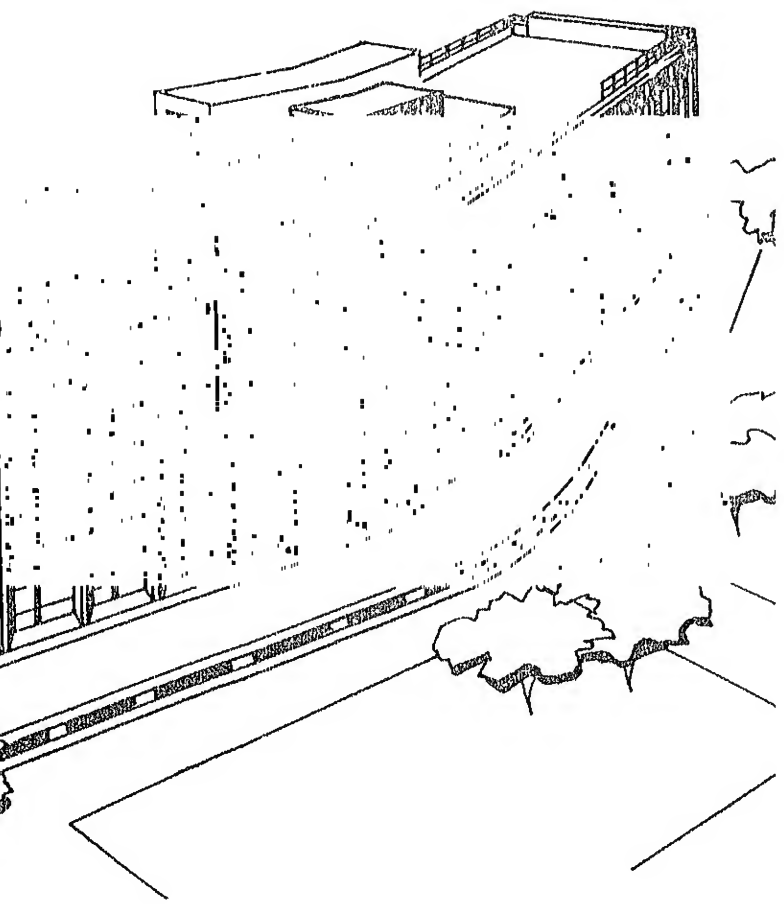

This report presents a collection of papers on the past and present concepts of the hospital environment and the principles for establishing and carrying out control programs. It is Volume III of a series of publications with the overall title, "Environmental Aspects of the Hospital," developed as a joint project of the Division of Hospital and Medical Facilities and the Division of Environmental Engineering and Food Protection of the Public Health Service. The chapters in the series were prepared by authorities who have extensive experience in their specialities, with particular reference to medical facilities.

ENVIRONMENTAL ASPECTS of the HOSPITAL

volume III SAFETY FUNDAMENTALS

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Division of Hospital and Medical Facilities and
Division of Environmental Engineering and Food Protection
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foreword

THE role of environment in health has received increased attention in recent years. Nowhere is control of environment more important than in today's hospital.

This volume is the third in a series prepared as a guide for those responsible for hospital environmental control programs. These volumes do not set forth standards to be uniformly followed in every hospital but rather they present basic principles upon which an individual program can be based.

The Committee on Environmental Engineering Aspects of Hospitals and Medical Care Institutions, listed on the following page, served as the review and advisory group on the content of the series.

Volume III enumerates safety principles and practices in the four main areas of risk within the modern hospital. Although the principal focus is on hazards from physical sources, laboratory practice is discussed because it is often as hazardous to the hospital staff as lack of proper infection control procedures would be to the patient. While specifics are basically dependent upon local codes and ordinances, safety programs can be best viewed as a series of fundamentals for planning purposes and for supervising employee conduct.

Other publications in the series deal with infection control, supportive departments, and administrative aspects of environmental control.

Major credit for these publications is due Robert L. Schaeffer, Environmental Research Consultant, who served as project director and coordinated the work of the two Divisions.

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FIRE AND DISASTER

James B. Black

SAFETY FROM FIRE and disaster in the hospital is an ever-increasing challenge which cannot be met by any system which does not place responsibility squarely on management. To fulfill this function, every hospital should appoint a Safety Officer, who should have a place in the administrative staff structure similar to that held by the head of purchasing or engineering. It should be clearly determined, and publicized throughout the hospital, that he will represent hospital administration in coordinating all efforts to reduce the possibility for human disability and property destruction. He should be the focus for direction of environmental control programs concerning fire prevention and the safe storage and handling of chemicals, pathogens, and radioisotopes. Whether the safety officer is directly charged with any or all of these various aspects, he is expected to assure himself and hospital management that these activities are being conducted in the best manner to protect the hospital and its employees, patients, and visitors.

The control of physical facilities and many of the conditions which lead to injury, disease, potential disability, and property damage have been discussed in other sections of this publication.* These include surveillance of food, water, and air for possible contaminants; vector controls; and waste disposal practices. Additional aspects which are managed directly by the safety officer are discussed below.

FIRE PREVENTION AND PROTECTION †

Prevention of fire outbreak, early detection, prevention of spread, prompt extinguishment, and evacuation may be accomplished through (1) emergency instructions, (2) training, (3) inspections, (4) design control, and (5) regulations.

Emergency Instructions

A brief plan should be posted in appropriate locations for all personnel to see easily, such as at alarm stations, hose cabinets, and bulletin boards. A somewhat longer instruction, including evacuation procedures, should be inconspicuously posted at nurses' stations. Patient evacuation procedures should be carefully planned, with special attention to off-hour or night-shift periods when limited staff assistance may be available.

A third instruction in detail should be distributed to all employees concerned with emergency plan implementation, such as switchboard and elevator operators, engineering staff, and emergency

* Although injuries from falls, burns, and similar occurrences constitute the majority of hospital accidents, fire prevention and emergency planning measures deal with hazards carrying a potentially higher severity rate and, consequently, are emphasized in this chapter. Background material on patient and staff accident prevention is offered in the "Additional Reading" at the end of this chapter.

† Large hospitals or medical care complexes often have a fire-fighting force directed by an installation fire marshal. He would, of course, perform the fire protection functions indicated as the responsibility of the safety officer.

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force members. A sample of the emergency instructions issued by the National Institutes of Health is shown in figure 1.

Training

All new employees should be trained in the use of extinguishers, activation of alarms, and evacuation procedures. Individuals most likely to fight fires, such as engineers, guards, housekeepers, nurses, and laboratory technicians, should be instructed in notification, extinguishment, and evacuation techniques using actual equipment.

A fire drill should be conducted at least quarterly on each of the three shifts. In patient areas, only limited evacuation exercises into adjacent isolation areas using ambulatory patients need be practiced. When drills are to be announced, a written "reminder" instruction to affected personnel serves as an effective training medium. (See figs. 2 and 3.)

Provision should be made for emergency generators, lanterns, and flashlights to provide light and power to critical areas such as operating suites, stairwells, communication equipment, fire pumps, and resuscitators. There should be emergency first-aid facilities for employees. Few things are as inexcusable as a hospital with no established system for handling a serious injury to one of its own people.

Depending upon the hospital's size and complexity, method of alerting personnel, and availability of public fire companies, emergency force teams should range from 9 to 15 members, including a plumber, electrician, and engineer. The teams should participate in exit drills scheduled for regular staff members and should be given instruction during this period in some phase of emergency control. In addition to the obvious skills of extinguishment, evacuation carries, ventilation control, and coordination with public fire companies, the emergency force should be briefed on techniques for controlling areas flooded from broken pipes, overflowing sinks, and storm seepage; on accidents and their control involving ventilation, gas, water, electrical, and piped oxygen systems; on the operation of emergency equipment; and on techniques to handle natural emergency situations that may result from hurricanes, floods, train wrecks, explosions, and so on.

The safety officer should arrange for maximum use of nearby public fire companies. This will include a written agreement about the type and possible limitations of emergency services, whether the installation safety officer or the municipal fire chief will take command, and reciprocal agreements for payment or mutual aid. Inspection schedules should include public firefighters to orient them to hospital structural layouts and the nature of unusual hospital hazards such as radioactive and pathogenic agent areas. (See fig. 4.)

The efforts of firefighters and building occupants, no matter how well trained, are ineffective

PROCEDURE TO FOLLOW IN CASE OF FIRE OR HAZARDOUS EMERGENCY

1. Remove patients from immediate hazard area and confine hazard by shutting the door. If patient is receiving oxygen, continue administration by using emergency equipment
2. Shut off oxygen in room where fire is discovered.
3. Sound fire alarm and dial 62222
4. Call all Nursing and Housekeeping personnel to the Nurses station by means of the INTERCOM.
5. Send messenger to the unit kitchen to request Nutrition and other personnel to report to the Nurses' station
6. Direct unit and emergency personnel to the emergency scene
7. Turn on all corridor lights.
8. Request ambulatory patients and visitors to walk away from the center of the building toward the adjacent cross corridors or through passageway into the North corridor, unless it is obstructed
9. Disconnect bell cords of bedridden patients located in the area adjacent to the immediate hazard zone, and evacuate (in bed) upon instructions from Medical Officer-in Charge. If the physician is not present the Nurse in Charge should evaluate the situation before determining the necessity for evacuation of a particular bed patient
10. All evacuated seriously ill or disturbed patients should be attended, if possible
11. After evacuation of all patients, CLOSE ROOM DOORS, and all corridor doors.
12. Make certain that all patients have been removed from the unit—check ALL ROOMS including treatment rooms, bathrooms, etc.
13. Instruct patients to remain in evacuated area and away from the area adjacent to the corridor doors Take census of patients.

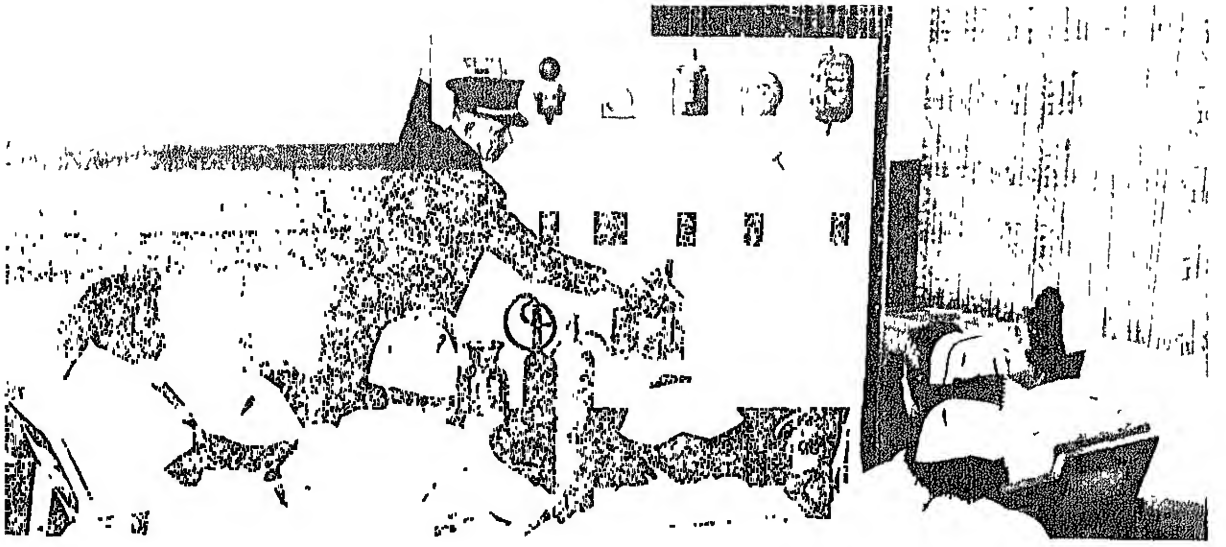
PROCEDURE IN UNITS OTHER THAN WHERE EMERGENCY OCCURS

1. When red flasher operates and emergency situation is announced over speaker system, all Nursing, Nutrition, and Housekeeping personnel should continue normal duties, but should review in their own minds, their preassigned duties in the event that patient evacuation is ordered.
2. Be alert for possible further orders via speaker system.
3. Return to normal duty upon the announcement over the speaker system that the emergency has ended.

NOTE. During period of emergency, do not use telephone unless it is imperative.

National Institutes of Health

Figure 1. **Sample of Emergency Instructions posted at nurses' station.**



'gure 2. Training lecture on fire alarms and hand extinguishers promotes basic familiarity with "primary action" needs among employees.

'gure 3. Outside demonstration of hand extinguisher illustrates proper use of specific equipment for different type fires.

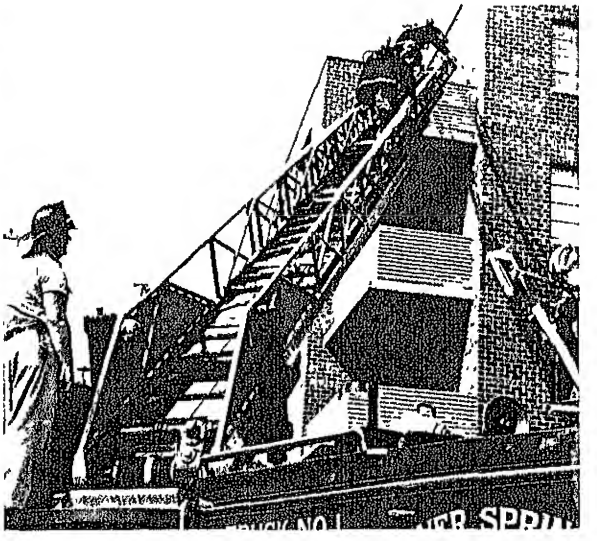


Figure 4. Fire drills using public fire companies promote familiarity of fire companies with hospital grounds and building floor plans.

'ithout reliable and strategically placed equip- ıent. Standpipe hoses, sprinklers, and water sup- lies should be provided according to the local fire ɔde. If there is no local fire code, generally ac- ɔpted codes should be consulted, such as the *Na- 'onal Building Code* or the Pacific Coast Build- ıg Officials Conference *Uniform Building Code*, eeping in mind the modifications necessary be- ıuse of the hospital's unique hazards.

The type and quantity of portable extinguishers should be furnished and located according to local ordinance or, in its absence, as indicated in Pamphlet No. 10 of the National Fire Protection Association (NFPA). In minimum hazardous areas (nursing and administrative areas) travel to an extinguisher should not exceed 100 feet, while in moderate to maximum hazardous areas (laboratories, paint shops, kitchens) travel should not ex-

ceed 50 feet. Data on capacity, size, suitability, range, and duration of streams of various types of liquid extinguishers may be found in NFPA Pamphlet No. 10.

Certain deficiencies and advantages of various extinguishers are as follows: dry chemical type is recommended in preference to the foam and carbon dioxide types for large grease fires because it will coat duct grease and will not be affected by ventilation draft as much as the carbon dioxide type. Since carbon dioxide is also effective on small grease fires and will not contaminate food several 5-pound sizes should be kept close at hand with a reserve of one or more 10-pound sizes. Dry chemical extinguishers should be filled with potassium bicarbonate (many refills are still sold with sodium bicarbonate powder). Commercially available dry chemical extinguishers that can be mounted and automatically actuated to safeguard dietary facility hood and duct systems should be encouraged both at the design stage and as modifications. Soda-acid and vaporizing liquid (mostly carbon tetrachloride) extinguishers should not be used. The soda-acid type is difficult to maintain and the volatile liquid type is not very effective, is toxic, and subject to failure because of plunger corrosion.

Inspections

The safety officer should see that all types of fire inspections are made satisfactorily and on schedule, including:

a. Inspections by the public fire department to orient their firefighters to the hospital plant and to coordinate plans with the hospital emergency force;

b. Inspection by the safety officer or the maintenance department of firefighting and alerting facilities such as the alarm system, fire extinguishers, water supply, standpipe hose system, and sprinklers;

c. Inspection by the safety officer to correct conditions such as trash accumulations; poor housekeeping practices; blocked or otherwise inadequate exits; open stairwell doors; paint-stuck hose cabinet doors; welding done without a permit or without sufficient fire protection; inadequately trained personnel; inadequate posted instructions; congested, overloaded or poorly maintained storage areas; and inadequately labeled utility controls;

d. Inspection by supervisors, followed by safety officer's spot check, for such hazards as:

(1) improper storage of flammable liquids and compressed gas cylinders;

(2) use of inadequate size ash trays (or none at all!);

(3) steam sterilizing of cellulose nitrate tubes (an explosion hazard);

(4) neglect in turning off Bunsen burners when personnel are not present;

(5) excessive lengths, quantities, and arrangement of extension cords;

(6) inadequate disposal facilities for hazardous chemicals;

(7) inadequate maintenance of operating suite conductive flooring and electrical equipment;

(8) no warning placards in immediate area of patients receiving oxygen therapy.

Design

Good design for new or modified buildings must be followed by an efficient review of plans and specifications by the hospital staff. Unfortunately, effective reviewing for fire safety factors is an art in which the usual hospital staff has little experience or competence. If such is the case, the hospital should seek assistance from the municipal fire chief.*

Although the scope of this text does not permit a detailed discussion of fire safety related design factors, engineers should be aware of at least one structural fault which continues to appear in otherwise well-planned facilities—omission of means to isolate a possible fire both horizontally and vertically. Major building sections and corridor intersections are sometimes not cut off from each other by firestop barriers extending from the ceiling to the solid structure above. Codes usually require that firestopping barriers be constructed to prevent spread of fire between stories,

* Fire chiefs in some communities are not officially responsible for structural aspects related to fire prevention, and, therefore, their favorable comments do not necessarily reflect legal approval. Where the local ordinances are inadequate, designers and reviewers should be requested to provide facilities above the minimum requirements of national building and fire codes.

in all open structural areas including attic and ceiling spaces (isolated into areas of 3,000 square feet or less), and such vertical openings between floors and walls as chases required by plumbing, ventilating, and electrical service risers. Elevator shafts and stairwells must be protected so that fire, fire gases, and smoke will not spread. Horizontal spread can be cut off by smoke barrier doors which are described in the latest edition of NFPA Pamphlet No. 101 entitled *Building Exits Code.* Areas of high fire hazard such as the paint shop should be isolated from patient areas by partition walls, fire doors, or preferably by location in a separate building as is required of boilers or other pressure-vessel installations.

Other faults which continue to be repeated are:

a. The installation of combustible acoustical tile. Flame spread index on any tile should not exceed 25;

b. Inadequate provision for handling trash and laundry. If trash and laundry chutes are used, the diameter should be large enough to prevent clogging. Sprinklers should be installed both at the top of the chute and in the receiving area. The charging doors should be fitted with positive latching and locking devices, and the utility rooms where trash and laundry are loaded on each floor should be isolated from the corridor;

c. Inadequate fire protection facilities for dietary facility hoods;

d. Permitting dead-end corridors. Exits should be as remote as possible from each other, although many code interpretations relax this principle in favor of symmetry and efficiency;

e. Installation of ventilation systems that are not adequately safeguarded with dampers and automatic shutdown devices such as thermostatic controls or a fire-gas-smoke detector that automatically shuts down circulating fans.

Regulations

Basic rules established by the hospital for fire protection and prevention should be included in the policy manual, or its equivalent, and should be made known to all employees and physicians. Brevity is desirable if such guidance is to be read and remembered, but it should include the obvious and commonplace safeguards that require compliance. Examples of supposedly obvious safety practices include disposal or containment of oily rags; turning off electrical and gas equipment when actual use is completed (such as irons and coffee pots in staff residences, and Bunsen burners and hot plates in laboratories); prevention of combustible waste accumulations, particularly in out-of-sight storage areas; and scrupulous observation of "No Smoking" areas.

Rules, which may need firm backing by management to enforce, include:

Keep stairwell doors closed at all times. This minimizes spreading of fire resulting from chimney effect, prevents rapid dispersion of fire gases, and permits escape by occupants and approach by firemen.

Keep room doors, corridor doors, and stairwell doors closed. Closed doors provide a temporary barrier against spread of fire and gases. (See fig. 5.)

Discard refuse promptly. Instruct housekeeping staff, as well as posting conspicuous signs, to discard promptly bulky refuse which will not fit into receptacles. Cut-paper packing should be discarded at the time the carton is opened. Trash should not remain overnight in the building or in

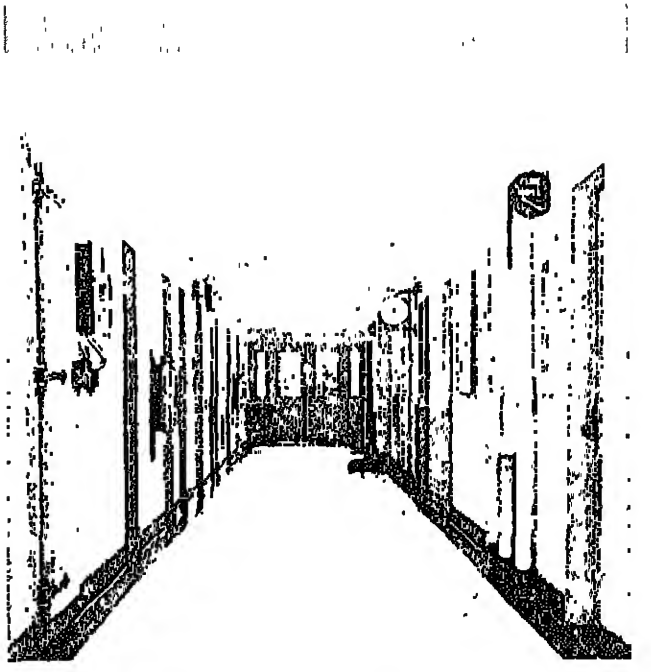


Figure 5. **Unobstructed corridors with hose cabinets well marked and hand extinguishers properly placed are basic to fire safety programs.**

the trash chute. Combustible waste baskets, which include some plastics, should not be permitted.

Do not discard chemicals into refuse cans. A special collection system should be established for collection of chemicals even though many of them may be innocuous.

Provide suitable ashtrays and depositors. Only ample capacity trays should be used. Sand urns should be replaced when possible with positively extinguishing depositors.

Free any paint-stuck equipment or apertures. Inspect windows, fire hose cabinet doors, and emergency oxygen control valve cabinet doors to see that they are not stuck fast with paint.

Identify utility controls clearly. Where hazardous equipment is to be used, as in a laboratory, electrical panel box circuits should be correctly identified and the door kept unlocked so that in an emergency, nearby room occupants may control receptacle circuits. Gas controls should be clearly marked and their location known to occupants of surrounding areas, as well as to the emergency force.

Do not store equipment or materials in corridors. Corridor storage presents an escape hazard, prevents isolation of combustible materials, exposes passersby to contact and exposure hazards, and interferes with firefighting operations. Where space is limited, one side of the corridor may be used for storage provided a clear width is allowed as prescribed by the *National Building Code.* Only metal cabinets, including refrigerators, should be allowed. No compressed gas cylinders, hazardous chemicals, or operating equipment should be permitted.

Require a welding permit and below-ground permit. Before an employee or contractor may use a cutting or welding torch or other flame-producing device (other than in the shop), or if he desires to enter a manhole, he should be required to obtain a permit from the safety officer.

Do not store flammable liquids in unsafe refrigerators. Only Underwriters Laboratory (UL) labeled explosionproof refrigerators or "Lab-Safe" domestic boxes should be permitted in laboratory areas. All refrigerators in the hospital should be clearly labeled either "Safe" or "Unsafe."

Do not smoke while fueling office duplicating machines. Flammable solvents and oxidizers

Figure 6. **Improper storage of flammable compounds such as ether can have disastrous results.**

spilled on the person can readily be ignited by a cigarette.

Confine work papers at night. Place work papers in desk drawers or metal cabinets at the end of the workday not only to safeguard data but to reduce readily combustible material left open to accidental ignition.

Learn to use fire extinguishers. All personnel should read and understand instructions. The safety officer should provide actual equipment demonstration. Personnel should not remove the pin or squeeze the trigger of an extinguisher except to extinguish a fire.

Figure 6 illustrates the hazards of improper storage of flammable compounds.

PLANNING FOR DISASTER

Hospitals are expected to assist in handling many types of disaster which may befall the community.

Examples of Poor Planning

In a small town on the eastern coast impractical emergency planning, combined with poorly coordinated community effort, resulted in chaos.

While the volunteer police organization was being entertained at an honorary banquet by the community, the party became aware of the increasing violence of the wind. Despite this ominous sign and earlier posting of hurricane warnings, the group took no action. As they headed for home, they encountered a severe traffic jam caused by other alarmed citizens also trying to get home. The situation was further complicated by numbers of the curious wanting to see what was happening. Untrained individuals were trying to unsnarl the traffic which had reached an almost hopeless condition before the volunteer police could get started. Clogged roads impeded maintenance of communication and power lines and transportation of injured to the hospital. Blocked hospital approaches necessitated extra manual handling of victims which in turn compounded their injuries. One hospital was quickly filled to overflowing while, through faulty planning, the other hospital in town was virtually ignored. The triage officer functioned as planned at the front hospital entrance. Unfortunately, the plan failed to include similar operations at the two side entrances. As a result, the hospital was flooded with minor cases which further dissipated the efforts of the medical staff. Municipal electric power was gone, and the hospital's local generator was inadequate to light corridors sufficiently to allow treatment of victims lying in the hallways. Even the supply of candles had to be rationed. A radio call for blood was made and the staff was astonished at the number of donors who volunteered. The blood was taken, but eventually the majority of it was wasted because the hospital had not provided adequate refrigeration facilities.

In another case involving a large patient care-research complex a part of the principal municipal electrical service failed, causing a partial loss of power and illumination. A secondary source of public power did not switch on because unused and uninspected automatic cut-in devices failed to function. Several hours elapsed before hospital management realized that a minor disaster was developing. This was indicated by overheated insulation of nurses' communication equipment and office calculators due to undervoltage, dripping of air conditioner evaporator coils, and the seepage of hydrogen sulfide from a laboratory into patient areas because the exhaust fans had stopped. An emergency order over the hospital paging system to shut down sources of hydrogen sulfide was delayed 5 minutes until approval to use the system which was on a circuit that was still functioning could be obtained from the administrator. One employee blocked open stairwell doors on five floors in a useless effort to ventilate the building, and engineers delayed opening the windows (locked with a special key to thwart interference with controlled pressures produced by the ventilation system) until official permission could be obtained. Elevators stalled between floors causing near panic because the lights and ventilating fans failed and the cab phones were useless. Phone transmitters were functioning but the lack of power prevented the receiver bells from ringing. Semifixed generators were started to supply limited power for critical areas, refrigeration, and lights, but the gasoline engines ran only a few minutes before exhausting their fuel. Additional fuel could not be obtained from the installation's supply because the pump operated on the nonexistent electrical power. One hospital executive, hoping to reduce the confusion, announced over the paging system that employees from some departments could be excused for the remainder of the shift. Because of lack of management coordination, he included personnel who were needed for the preparation of patient food.

As ludicrous as these examples may appear, they resulted from the actuation of elaborate plans conscientiously conceived but not given the full-dress rehearsals that would have displayed flaws that became apparent only too late.

Emergency Planning Committee

The appointment of an Emergency Planning Committee is the most critical ingredient in establishing a successful disaster control program. Through this committee, plans may be kept alive and modified as changing national and community conditions dictate. There is no standard composition of a disaster planning group, but it should include whatever representation is needed to assure services of medical, nursing, administrative, identification and records, food service, building maintenance, supply, and transportation personnel. Planners should be expected to:

1. Review specific areas, conditions, and assumptions for which detailed plans should be established to cope with national and local emergencies;

2. Assign responsibility for developing these

plans to appropriate staff and operating personnel of the hospital;

3. Coordinate hospital plans with the needs and facilities of the community;

4. Review and recommend developed plans for acceptance by management;

5. Periodically review and adjust existing plans to meet current demands;

6. Assure that all appropriate plans are communicated to individuals and organizations responsible for their implementation and that these individuals and groups are trained for maximum effectiveness.

The Emergency Planning Committee may begin by preparing a broad strategic outline for handling maximum disaster such as enemy attack, but which can be modified to cope with lesser occurrences such as internal fire, hurricane, flood, or epidemic.

The planners should next assign responsibility to appropriate staff and operating personnel to develop specific procedures in areas identified in the strategic outline. Basic definitions and checklists should be provided to enable all participants to develop specific plans using similar formats and common objectives. Plans should be brief and flexible to enable the handling of an epidemic as readily as a variety of traumatic casualties. Assigned titles and tasks should be as closely related to normal duties as possible. An alerting system should be established to convene the Emergency Planning Committee for a prompt situation evaluation. Capacity assumptions for patients and those seeking public shelter should be ascertained to aid in realistically determining procedures and supply requirements. For example, relative proportions may be developed such as a 10 percent increase in patients for a local accident, a 100 percent increase for natural disaster, and a 1,000 percent increase for enemy attack. Although the overall plan should be based on maximum use of the hospital, it should work equally well under proportionately less adverse conditions requiring partial use.

Plans should be coordinated with the needs and facilities of the community. Full cooperation should be sought with Civil Defense, local authorities, and private, military, and municipal ambulance groups. Local agencies can also provide information, help with supplies such as additional electrical power, water, food, medical supplies, radiological monitoring equipment, Civilian Defense Emergency Hospital (CDEH), and trained tradesmen and technicians.

The Committee should assemble specific emergency operation plans from staff members and ensure that they are in a consistent format. Each instruction should be prepared in looseleaf style for easy distribution of specific portions to appropriate personnel. To the extent possible, duties required of categories such as nurses, maintenance men, and patients should be grouped so that individuals only have to familiarize themselves with relatively short sections of the overall plan. The use of a looseleaf booklet also permits the updating of instructions without a complete reissuance of the overall plan.

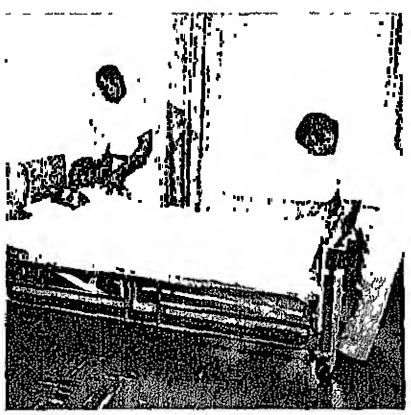


Figure 7a. **Washable fabric patient-carrier that fits over mattress is folded around patient.**

Figure 7b. **Patient is lifted from bed.**

Figure 7c. **One man can evacuate one nonambulatory patient regardless of patient's size.**

The Emergency Planning Committee should see that all appropriate plans are communicated to individuals and organizations responsible for disaster aid and that personnel are periodically trained. At least two casualty drills should be conducted annually to meet the recommendation of the Joint Commission on Accreditation of Hospitals. An easily understandable handbook or condensed plan, supplemented by a basic checklist of procedures, should be made available to all employees. A comprehensive emergency operations plan should be distributed to supervisory personnel. The Emergency Planning Committee should see that training programs are established for outside personnel such as power utility teams, social workers, messengers, and clerical volunteers. Medical self-help lectures on how to erect CDEH equipment should be conducted for hospital personnel. Planners should maintain liaison with local medical societies to assure an emergency staff of physicians. The Committee should provide information on Medical Education for National Defense (MEND) to encourage professional staff to seek training in the care of mass casualties.

Obviously, this brief treatment of a complex subject is intended only to encourage preparation of effective disaster plans. A *Check List for Hospital Disaster Planning*, available from the American Medical Association's Committee on Disaster Medical Care, will be useful in assuring that all aspects are included in a proposed plan.

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Chapter II

RADIATION SOURCES

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X-RAY SOURCES AND NEED FOR PROTECTION

While recognizing the benefits derived from the judicious uses of ionizing radiation in medical practice, most authorities agree that it does constitute a public health problem.

Effects of Radiation Exposure

Tissue injuries from X-ray exposure began to be reported soon after Roentgen announced in 1895 his discovery of this new form of radiation. These injuries were recognized first among individuals experimenting with unshielded X-ray equipment. Skin burns of varying degree were observed, usually involving body parts in closest proximity to the X-ray source. The hands, for example, were commonly involved. Loss of hair in the exposed parts was observed, and in some individuals a chronic dermatitis of the irradiated skin appeared. As time went on tumors developed in some of these early X-ray pioneers; the cause and effect relationship was first recognized when tumors appeared locally in those parts of the body that had shown earlier evidence of severe overexposure to X-rays.

Yet, this very ability of X-rays to injure tissues was quickly recognized as beneficial when used judiciously. Tissues of some forms of cancer were found to be much more sensitive to X-ray effects than were normal tissues. This early finding led to modern radiation therapy in which relatively large doses of ionizing radiation are commonly used to damage tumor cells, in some cases to do lethal damage to the tumor and in other instances to interfere with its growth and spread, while at the same time limiting the radiation damage of normal tissues to acceptable level.

One of the early and relatively crude means of determining the output of an X-ray tube was the erythema dose, an amount sufficient to cause reddening of the skin. An early goal in X-ray use for diagnostic purposes was to improve fluorescent screens and X-ray sensitive film to the extent that satisfactory diagnostic examinations could be done without causing erythema of the subject's skin. In the case of individuals using X-rays in their work, it was soon learned that erythema or other serious sequelae of exposures to large doses of radiation could be minimized by limiting duration of exposures, fractionating doses over a period of time, increasing distance from the source, or using shielding.

Speed is imperative in most radiographic examinations to stop motion. In a fraction of a second with modern X-ray equipment an electrical current flows in an X-ray generator, hurling high-energy electrons across a vacuum to an abrupt halt as they strike a heavy metal, such as tungsten, where the kinetic energy of the electrons is converted into heat and X-rays. Millions of X-rays, each a packet of energy capable of passing through various materials with the speed of light, are produced in the vacuum tube during the brief exposure. Many X-rays are prevented from escape by the shielding used in the construction of modern X-ray tube housings, but a stream of X-rays directed toward the subject strikes the body. Many

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of the X-ray energy packets are absorbed by the subject during the momentary exposure and are scattered within the irradiated object. Some of the packets emerge, still traveling at the speed of light, but the pattern of the emerging X-ray field has been altered by passage through materials of varying thickness and density, such as skin, fat, bones, muscle, blood vessels, and lungs. Ideally, all these events should take place in a fraction of a second so that the image will not be blurred by motion.

When one understands that even small doses of ionizing radiation are sufficient to produce the striking and permanent changes in X-ray film with which health personnel are familiar, it is easier to appreciate the concern expressed by geneticists and radiobiologists that such exposures, commonplace in modern life, may cause significant and even permanent changes in the human cells. As with exposed X-ray film, the effects may not be obvious immediately but may appear later after other forces have been brought into play.

There is little doubt that a cause and effect relationship exists between the ingestion of radium by some radium dial painters in the period of World War I and their development of bone changes, bone tumors, and cancer. There were no outward manifestations of impending disaster among those individuals. But one might not expect early external manifestations since in their situation most of the radiation dose was delivered to internal body structures. There seems to be an obvious relationship between the early skin damage of some X-ray pioneers and their later development of cancer in the damaged tissues. There were reasons to suspect a relationship between large radiation doses and the later development of aplastic anemia in some early radiation workers.

Time, distance, and shielding came into use to reduce exposure of personnel working with radiation. Physicians and dentists were warned to keep their hands away from the X-ray tube and beam, and, as a result, the incidence of skin burns among radiation workers fell. An erythema dose to the skin of a radiation worker has been a rare event in the past 30 years. Yet, recent studies show conclusively that among radiologists, who as a group can be expected to have been exposed to more ionizing radiation than other physicians or the general population, there is a statistically higher incidence of leukemia than occurs in other groups. Studies of the Japanese by the Atomic Bomb Casualty Commission reveal a striking relationship between radiation doses and subsequent development of some forms of leukemia among survivors of the atomic bomb raids of 1945.

Radiation exposures of the reproductive cells are likely to cause genetic changes. Studies suggest that heat and certain drugs or chemicals may also induce genetic change, perhaps to a degree that overshadows the potential hazards from radiation. Our present understanding of all the factors contributing to genetic changes is, however, incomplete.

Natural Background Radiation

Man has evolved through eons of time in the presence of radiation. Natural background radiation arises from cosmic radiation, terrestrial objects, building materials around us, and normally radioactive materials in our bodies. Epidemiological studies thus far have been unable to demonstrate that variations in levels of exposure to natural background radiation have had biological consequences in the population groups involved. Average radiation dose from natural background radiation for the population of the United States has been in the order of 120 millirem (mr.) each year. This dose, which is approximately the same for the whole body including the reproductive cells, is delivered gradually. It amounts to about ⅓ mr. each day, about $\frac{1}{100}$ mr. each hour, or about $\frac{1}{360,000}$ mr. each second.

Recommended Occupational Exposure Limits

For over 30 years, national and international authorities have been establishing exposure limit standards for radiation workers. In addition, means have been found to reduce radiation exposures in industry. This is fortunate since, with evidence accumulating to suggest the potential hazards from even relatively small radiation exposures above background level, the recommended limits for occupational exposures have gradually lowered.

Special limits have been set for the skin, certain internal organs, and the hands and feet since experience shows that these tissues seem to tolerate larger radiation exposures without undue risk. For most body tissues, however, including the

head, trunk, and reproductive cells, the generally recommended limits for radiation workers at present are about 100 mr. per week, or about 5,000 mr. (5 r.) per year. More stringent limits have been set for those individuals who are not radiation workers but who may be incidentally exposed to ionizing radiation in the course of their work. Actually, many of the standards set quarterly limits rather than weekly ones to provide more flexibility for radiation activities. According to these limits, the radiaton worker obviously may be subjected to exposures that exceed natural background radiation. It is also obvious that some degree of radiation exposure must be allowed if people work with X-rays, radium, radioisotopes, and various forms of atomic energy.

RADIATION SAFETY STANDARDS

Over the past few decades the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) have provided guidance in establishing radiation safety standards. Their recommendations have been used, for example, by the U.S. Atomic Energy Commission (AEC) in setting radiation standards for their employees, contractors, and licensees. Several States and some cities have adopted radiation standards on permissible exposure limits for individuals occupationally exposed to radiation, as well as limits for those in the immediate vicinity of radiation installations. Hospitals in some States may find that their isotope activities are subject to AEC standards while their X-ray and radium programs are subject to State standards. In States that have entered into agreement with AEC to do so, the State will operate the regulatory program not only for X-rays and radium but also for medical uses of radioisotopes. Environmental health personnel involved with radiation safety should keep abreast of the latest standards in effect in their community.

Federal agencies have been subject since 1960 to standards set by the Federal Radiation Council. The U.S. Department of Labor has promulgated standards for radiation control that apply to activities carried out under contract for the Federal Government. Other Federal agencies have radiation standards that apply specifically to activities carried out within the particular agency.

Model State Radiation Control Regulations are available from the Public Health Service, the Atomic Energy Commission, and the Council of State Governments. None of the standards contains a specific limit on the number of radiation exposures or the doses to which an individual or the general population may be subjected for medical and dental reasons. Some standards have a limitation that such exposures be made by, or under the direction of, an individual licensed to practice the healing arts in that State. The consensus has been that it would be impractical and improper to intrude further into this aspect of the patient-doctor relationship.

A study in the United States reported in 1956 suggested that X-ray contributions to genetically significant gonadal doses may have begun to exceed the contribution from natural background. An interesting finding in most of the early studies on X-ray was that a considerable proportion of the gonadal doses associated with its use could be prevented by modifications of equipment, supplies, and techniques associated with operation of X-ray equipment. The majority of X-ray installations studied in a series of radiation surveys were deficient in one or more areas of modern radiation safety. In many instances very simple and inexpensive modifications have led to remarkable reductions in needless radiation exposure.

State Radiation Programs

Most of the changes now being made to reduce needless subject exposures enhance rather than impair the fluoroscopic image or radiograph. This is one reason that every State now has undertaken some type of radiation safety program involving X-ray users. These programs vary from State to State, depending upon a number of factors. In some States the programs have involved dental X-ray installations on a large scale, while in other States the early emphasis has been on X-ray installations in hospitals or the machines in offices or clinics of physicians, veterinarians, or chiropractors. In States having sufficient personnel and equipment, practically all X-ray machines have been checked. Many States have a considerable task ahead to reach all their X-ray users. Some 200,000 X-ray units are in use throughout the Nation; this indicates the magnitude of the problem.

Relatively few hospitals in the United States have a sufficiently large radiation program to warrant a full-time staff specialist in radiation safety. Few of these centers possess adequate monitoring equipment. The experience gained by the States in their monitoring programs will be helpful in the development of a monitoring kit for use in a radiation center. Rather than invest almost $1,500 in radiation monitoring equipment, however, many hospitals prefer to utilize the talents—in terms of equipment and experienced personnel—available from public health agencies. Even in large medical centers with a satisfactory complement of radiation monitoring equipment and personnel knowledgeable in radiation safety, the staff may find it helpful to obtain the State radiation control regulations and sample inspection forms. The trained environmental engineer can play an important role in establishing a centerwide radiation safety program. He can aid in the interpretation of State and AEC radiation standards. He should help formulate working rules and standard operating procedures appropriate for the institution and aid in the planning in-service radiation control training programs.

Training

Training in the principles of radiation safety is available from a variety of sources. Several universities offer graduate training in radiological health, some offering Public Health Service traineeships, and others participating in AEC fellowships. Intensive short courses of 1- to 2-weeks duration conducted by the National Center for Radiological Health of the Public Health Service, while organized mainly to assist State and local health agencies, may accommodate other students when space permits. When the demand has been sufficient, State and local health agencies have organized short courses that attract a variety of disciplines. In some larger cities regularly scheduled lectures in radiation safety have been arranged as part of the resident training in radiology. The hospital environmentalist may wish to attend these sessions. Various forms of training sometimes can be arranged through the local chapter of the Health Physics Society or the county Radiological Society.

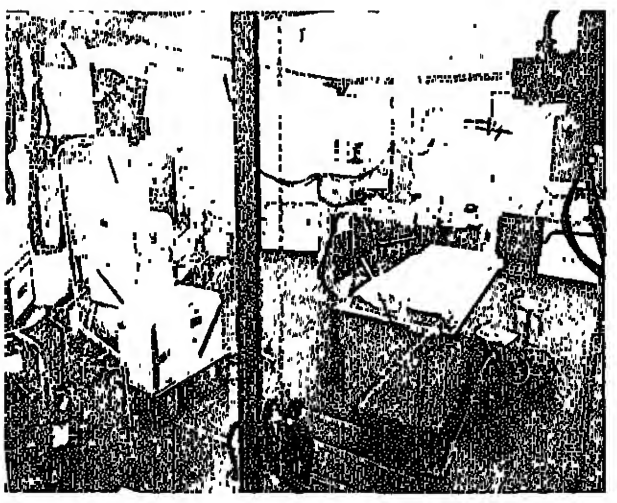

Figure 8. **Modern radiology equipment in diagnostic room poses complex engineering problems of planning, installation, and maintenance.**

Factors in Radiation Safety

The hospital environmentalist will find that the elements of radiation safety can be considered in many different ways. One convenient mechanism is to determine whether a factor relates to protection of the patient only, the radiation staff, or individuals living or working in the vicinity of the radiation installation. Some factors relate to more than one category. In most cases, a factor that is advantageous in one regard is also advantageous in one or more of the other categories, although the degree of benefit may not be the same in each. (See fig. 8.)

Factors in radiation safety could also be considered in terms of equipment (nonexpendable), supplies (expendable), techniques (how the equipment and supplies are used), and judgment. Physicians and dentists for example, may be particularly sensitive about radiation control efforts that might seem to question their professional judgment and their patient-doctor relationship.

X-ray Beam Size. One of the factors that has contributed significantly to needless radiation exposure has been the excessive size of the X-ray beam. Too large a beam can cause increased scatter radiation, thus increasing the occupational exposure of radiation personnel. Far more significant has been the needless exposure of patients, the whole population gonadal dose having increased as a result of improper selection of beam-limiting cones for radiographic procedures. Chest

X-ray examinations are not an ideal example because the radiation exposures in individual cases are relatively small in comparison to abdominal X-ray procedures. Yet chest X-rays warrant mention because they are so common and because the difference in gonadal dose can be so great on the basis of this one factor alone. Conventional chest X-ray examinations are the most common medical radiographic procedure in this country, with some 30 million such exposures each year. Some of these cause gonadal doses so small as to almost defy detection by the most sensitive means. Especially is this true where modern equipment is used by technicians who are careful to make the proper adjustment of beam-limiting devices. Yet several studies have shown that more than 60 percent of the medical X-ray machines in a community where there has not been an *active program* in radiation control are likely to be operating with X-ray beams larger than either desirable or necessary. For individual male subjects this means a 450-fold increase in gonadal dose and for females up to 100-fold increase above the dose when beam size is restricted by the proper cone or proper setting of variable aperture collimators.

With experience, one suspects an excessively large X-ray beam the moment he enters a medical radiographic room if the X-ray tube lacks any cone whatsoever or if a large "multipurpose" cone is attached to the tube housing. Use of the geometric proportions, after one has measured the cone orifices and knows the distance at which exposures are made, is another way to estimate the size of the X-ray beam reaching the patient. Most X-ray survey or monitoring kits, however, contain calibrated strips of fluorescent material that can be placed at the plane of interest, a brief X-ray exposure made, and the dimensions of the X-ray beam, its shape, and any errors in angulation or alignment determined. While it soon becomes routine with the survey team, this demonstration has been found most effective repeatedly in calling the attention of the X-ray equipment operator to the importance of selecting the proper beam size. All cones commonly used on the X-ray machine should be checked and calibrated. Pertinent data can be affixed to each cone by use of stickers or tape to provide a necessary reminder to operating personnel.

Most X-ray engineering and safety survey teams prefer to avoid operating a radiographic machine. During a survey they ask that any necessary exposures be made only by one of the hospital staff who has day-by-day familiarity with the machine. X-ray cassettes can be opened at the plane of interest so screens can be used to display the X-ray beam when an exposure is made. This method requires total darkness in order for the wave lengths of blue light to be perceived by the human eye, and, consequently, the method has limited application in some X-ray rooms during daylight hours. Full sheets or smaller strips of X-ray film can be used in cassettes that are set out in a pattern at the plane of interest to measure the dimensions and other characteristics of the X-ray beam. Since this method is tedious and relatively expensive in comparison with using the fluorescent strips, it is not ordinarily used in surveys. Nevertheless, the technique is a simple and convenient means to determine beam size in a survey where personnel and special survey equipment are limited.

In terms of beam size, the ideal would be one large enough to include the physical structures of interest but no larger than the size of the film on which the X-ray image is recorded. X-ray film usually is rectangular in shape with a 4 : 5 ratio of width to length, while X-ray cones commonly produce a round beam. Variable aperture collimators are available for use with some radiographic machines, and these permit the beam to be adjusted close to the desirable size with ease and accuracy. When cones must be used, however, some authorities feel that it is reasonable to require that the diameter of the circular beam produced by such cones not exceed by more than 2 inches the diagonal measurement of the film being exposed. This provides some leeway for the alignment of the X-ray beam. More stringent limitations on beam size might ruin some radiographic exposures and necessitate repeating the examination which would defeat the purpose of X-ray radiation safety programs. Specifically, a circular beam not more than 24 inches in diameter is considered as large as necessary to expose a 14- x 17-inch film whose diagonal measurement is about 22 inches. If a light-beam localizer is used, the beam size for a 14- x 17-inch film properly should not exceed the film size by more than an inch in either direction when a variable aperture collimating device is used at a 72-inch tube-to-film distance.

If nothing else were accomplished, a widespread improvement in reducing the size of X-ray beams to reasonable dimensions would probably be more

significant than all other efforts at radiation safety and control, even if attained.

X-Ray Machine Filtration. Generally less important than beam size, the filtration of an X-ray machine is usually checked and compared against standards in State radiation control regulations or the suggestions in National Bureau of Standards Handbook 76. Ordinarily, about 2.5 mm aluminum filtration is needed, although there are some exceptions with which the radiologist will be familiar calling for less filtration for special soft-tissue techniques such as mammography. Portable X-ray units and older radiographic machines often lack filtration sufficient to meet modern standards. Sheet aluminum of essentially pure, X-ray quality can be trimmed easily with tin snips or heavy scissors to fit into the filter slot if there is any difficulty getting a filter from an X-ray supplier.

Shielding. Some indication of the adequacy of shielding in walls and floors can be gained from review of building plans and, occasionally, by visual inspection of walls and door frames. More precise data should be obtained by measuring exposure rates in shielded areas by use of ionization chambers. Care must be taken, however, to translate exposure rates into more meaningful numbers by considering occupancy and use factors as well as direction of the X-ray beams. Because of the complexities involved in estimating all these variables, some authorities feel that more reliable data is provided by using fixed-position film badges exposed for an adequate period of observation at points of interest. Properly worn individual film badges have proven useful for assessing exposure of radiation personnel.

Scatter Measurements. Scatter measurements are a common part of a radiation safety survey. Dose rates on the dial of an ionization chamber must be translated to include the considerations mentioned above. Unless a suitable phantom is used as a scattering agent, the measurements may be deceptively low. The number of measurements should be limited so that too great a heat load is not put on the X-ray tube.

Tube Housing Leakage. While assessment of the housing leakage has been a prominent part of radiation safety surveys in the past, most authorities feel that in the brief time available to survey an X-ray unit more important things can be done. Excessive leakage of the tube housing is quite rare in well-designed, modern X-ray units, although leakage has been found in old machines and off-brand tube housings. Care must be taken to choose a proper use factor when translating an exposure rate measurement of the leakage of the tube housing. Thin sheet lead can sometimes be used to correct the situation if the tube housing leakage exceeds the limits set in State regulations.

Fluoroscopic Exposure Rates. The "tabletop exposure," or the dose rate at the panel of upright units, is checked as part of the survey of a fluoroscope for comparison with the State regulations or the NCRP recommendations in NBS Handbook 76. Condensor-R chambers have been used to measure these relatively intense X-ray beams, but, hopefully, more convenient and less expensive instrumentation may be available in the future. Again, care must be taken to avoid overloading the X-ray tube during the prolonged exposures that are customary in determining fluoroscopic exposure rates. For purposes of standardization and to minimize the dangers of inadvertent exposure of survey personnel, a 4- x 4-inch beam at the table top is routinely used when making these determinations.

Other Fluoroscopy Factors. Radiation leakage through the glass cover of a fluoroscopic assembly can be checked by using an ionization chamber. Although it is relatively rare, these surveys have uncovered plain glass in some units instead of lead glass, which can account for a substantial difference in the exposures of the fluoroscopist.

The shutters of some fluoroscopes are improperly adjusted, allowing the primary X-ray beam to pass the fluoroscopic assembly and strike the fluoroscopist. Parts of his body may be exposed to doses more than 1,000 times the customary scatter doses if he is in the primary beam. The fluorescent strips in the monitoring kit are used to check the shutters. An X-ray repairman is the most qualified person to correct any deficiency.

Lead gloves and aprons are often found to have cracks or other defects that may lead to needless exposure of radiation personnel. Sometimes these defects can be detected by palpating the gloves and aprons, but radiographic examination is more satisfactory.

Safety Surveys. While the person in charge of radiology in a large medical center is well aware of the X-ray machines under his jurisdiction, the

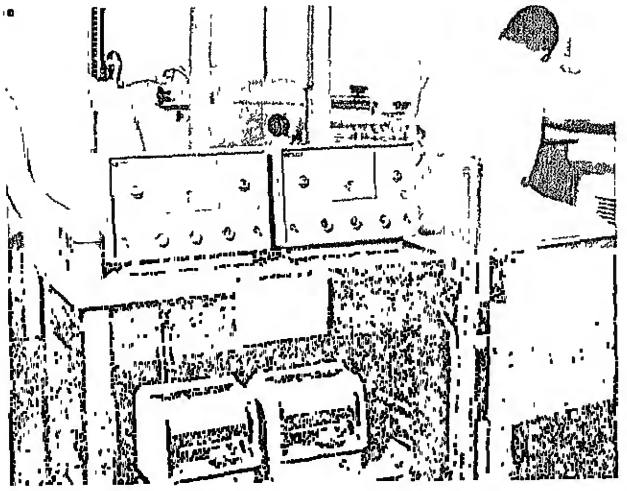

Figure 9. Portable renography equipment used at bedside.

hospital environmentalist may find that the control of some other X-ray units, such as those in surgery, urology, or the outpatient department, is not always clear-cut. Considerable planning may be necessary to arrange a comprehensive radiation safety survey in a large medical center. Decisions will have to be made concerning the extent that X-ray and radiation personnel will be expected to take part in the survey, the extent to which the survey personnel will be permitted to discuss their findings with X-ray technicians, the type of report, and to whom it will be sent.

In small hospitals, the hospital administrator, perhaps to his surprise, may be the official responsible for radiation safety when there is no full-time radiologist.

Insofar as radiation therapy is concerned, the hospital environmentalist should be certain that a qualified expert periodically checks this aspect of radiation safety. (See fig. 9.) In addition, he should take part in the survey when the expert visits the hospital.

Recommendations pertaining to the control of X-ray use in the healing arts are to be found in Part E of the Council of State Governments' *Suggested State Regulations for the Control of Radiation.* (See Additional Reading.)

The hospital environmentalist should familiarize himself with AEC or State standards that apply to the possession and use of radioisotopes. An intramural program is usually necessary to assure that the isotope users in a medical center continue to store, use, and dispose of the radioactive materials in accordance with official standards and any additional rules that may have been adopted by the institution's radiation committee. The hospital environmentalist should be with the AEC inspector throughout an inspection visit.

SAFETY MEASURES WITH RADIOACTIVE MATERIAL

The following material constitutes sections 6 through 11 of the *Radiation Safety Manual*, developed by Joseph J. Fitzgerald for the Committee on Isotopes of the Massachusetts General Hospital and revised, 1963, by Edward W. Webster, Ph. D. It is included * here not only for its technical content but also as an example of an internal document developed by a large medical center. Similar documents have been developed by other medical facility complexes, varying according to State licensure and regulation and specific individual program needs within the institution. It is felt, however, that this document is a good example of locally developed guide material.

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RADIATION SAFETY MANUAL
Sections 6 Through 11

Section 6.0 RULES FOR THE SAFE HANDLING OF RADIOACTIVE MATERIALS

6.1. Classification of Areas

6.1.1. Unrestricted Areas

An area is unrestricted and does not require control measures:

a. if an individual continually present in the area cannot receive more than two mrem in any one hour or 100 mrem in any 7 consecutive days to any portion of the body; or

b. if, when allowance is made for expected occupancy and time variations in dose-rate, no individual is likely to receive more than 500 mrem in a calendar year.

6.1.2. Restricted Areas

All areas within the hospital in which dose levels do not conform to the standard for unrestricted areas shall be restricted and under the control of the Radiation Safety Officer for radiation safety purposes. A sign carrying the words "Radiation Area—No Entrance to Unauthorized Personnel" shall be prominently displayed at the entrance to each restricted area, and the licensee responsible for work with radioisotopes in that area shall be responsible for controlling access to the area.

Both Federal and State regulations define restricted areas containing radiation which require special control measures as follows:

a. *Radiation Area.*—Any area accessible to individuals in which there exists ionizing radiation at such levels that a major portion of the body of such individuals could receive an absorbed dose greater than 5 mrem in any 1 hour or 100 mrem in any 5 consecutive days.

b. *High Radiation Area.*—Any area accessible to individuals in which there exists ionizing radiation at such levels that a major portion of the body could receive in any 1 hour an absorbed dose greater than 100 mrem.

6.2. Maximum Permissible Dose Levels

6.2.1. In restricted areas, control must be such that no individual over 18 years of age [1] (excluding patients) will receive in any 1 calendar quarter, a dose in excess of the following limits, except as specified in 6.2.2.

Whole body, head and trunk, active blood-forming organs, lens of eyes or gonads	1.25 mrem
Hands, forearms, feet, ankles	18.75 rem
Skin of the whole body	7.5 rem

6.2.2. Doses to the whole body in excess of the above limits are permitted providing that during any calendar quarter the dose does not exceed 3 rem and that the cumulative dose does not exceed 5 (N−18) where N=age in years.

6.2.3. The maximum whole body exposure of individuals under the age of 18 must be limited to 0.5 rem per calendar year.

6.2.4. All areas in the vicinity of the hospital, which may be irradiated by sources under the control of the hospital, shall meet the standards in 6.1.1. for unrestricted areas.

6.2.5. Contamination Levels

Radioactive contamination levels of air and water in restricted areas must be controlled such that the levels in $\mu c/ml$ specified in 10 CFR 20 [2] appendix B, table I, are not exceeded.

6.3. Personnel Monitoring

Personnel monitoring devices are required by law and records must be kept, if an individual receives or is liable to receive a dose in any calendar quarter in excess of 25 percent of the values in Section 6.2 (5 percent for individuals under 18).

Such monitoring will normally take the form of film badges worn on the chest or at the waist, and shall be mandatory in all areas requiring a "Radiation Area" sign. Where the hand dose may exceed 25 percent of the relevant limit in 8.2., ring or wrist film badges must be worn.

Where the nature of the radiation or the unusual level of the possible exposure dictates their choice, personnel dosimeters of the ionization type should be worn and readings recorded daily.

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[1] Persons under 18 years of age (excluding patients) should not be permitted access to restricted areas.

[2] Code of Federal Regulations—Title 10, Part 20.

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A guide concerning the advisability of wearing film badges is included as appendix 3.

6.4. **Posting of Areas and Other Required Labels**

Signs are required by law to denote areas or containers with levels of radiation or radioactivity specified in the following sections.

6.4.1. **Caution Radiation Area**—in areas accessible to personnel in which a major portion of the body could receive in any 1 hour a dose of 5 mrem or in any 5 consecutive days a dose in excess of 100 mrem.

A sign is NOT required:

a. on a room containing a sealed source if the radiation level 12 inches from the surface of the source container of housing does not exceed 5 mrem/hour.

b. in rooms or wards with patients containing radioactive materials, or containing radioactive materials for less than 8 hours, provided that there are personnel in attendance to prevent exposure of individuals in excess of the levels of 8.2.

6.4.2. **Caution Radioactive Material**—in areas in which radioactive material is used or stored in amounts exceeding these in table II, column I, (taken from app. C 10 CFR 20), on containers in which radioactive material is transported, stored or used in amounts exceeding those in table II, column II (taken from app. C 10 CFR 20).

When containers are used for storage, the labels shall state the quantities and kinds of radioactive materials and the date of measurement.

A label is NOT required if the concentration of the material in the container does not exceed the maximum permissible concentration for occupationally

Table II.—**QUANTITIES OF SOME RADIOACTIVE MATERIALS REQUIRING SIGNS**

	Column I Minimum Quantity for Radioactive Material Sign in Room	Column II Minimum Quantity for Radioactive Material Label on Container
RADIOISOTOPE	MICROCURIES	MICROCURIES
As-76	100	10
Au-198	100	10
C-14	500	50
Ca-45	100	10
Cl-36	10	1
Co-60	10	1
Cr-51	500	50
Cs-137	10	1
Cu-64	500	50
F-18	500	50
Fe-55	500	50
Fe-59	10	1
H-3 (HTO or H_2^3O)	2,500	250
I-131	100	10
K-42	100	10
Na-22	100	10
Na-24	100	10
P-32	100	10
Po-210	1	.1
Ra-226	1	.1
S-35	500	50
Sc-46	10	1
Sr-89	10	1
Sr-90+Y-90	1	.1
Y-90	10	1
Zn-65	100	10
Unidentified	1	.1

This table is based on app. C, 10 CFR 20, November 1960.

exposed individuals (10 CFR 20 app. B, table I, col. 2); or for laboratory containers such as beakers, flasks and test tubes, used transiently in laboratory procedures, when the user is present.

6.4.3. Other signs are required for HIGH RADIATION AREAS (dose-rate greater than 100 mrem in an hour) with the above exceptions, and in Airborne Radio Activity Areas. The radiation safety officer must be consulted regarding control measures in these areas.

6.5. Surveys

Work areas should be monitored for contamination by the licensee or his delegate after work with radioactive materials. Regular surveys shall be conducted at least weekly, and the survey results recorded, for all areas in which radioactive materials are used routinely.

6.6. Handling of Radioactive Materials

1. Before any work is undertaken with quantities of radioisotopes which may produce significant external or internal exposure, attention shall be given by the licensee to precautionary measures including the use of hoods, remote handling equipment, air monitoring. The Radiation Safety Officer may be consulted for recommendations on specific operations.
2. Work which may result in contamination of work areas shall be done over stainless steel trays or trays lined with heavy absorbent paper.
3. Personnel working in areas containing radioactive materials shall wash their hands thoroughly, using plenty of soap, before eating, smoking or leaving work. Those working with unsealed sources should monitor hands and shoes upon completing operations.
4. Eating, storing, or preparation of food is forbidden in a laboratory or rooms where work with unsealed radioactive sources is taking place or where contamination may exist.
5. Smoking is not permitted in areas where work with unsealed radioactive sources is in progress or where contamination may exist. Under no circumstances should cigarettes, cigars or pipes be laid on tables or benches where radioactive work has been or is in progress.
6. Pipetting by mouth is not permitted, unless the concentrations are less than 1,000 times the maximum permissible concentrations in water for occupational exposure listed in 10 CFR 20, appendix B, table I. Permission will be granted by the Isotopes Committee for mouth pipetting only if there is strong justification, if proper safety procedures are observed (e.g., water traps) and if the licensee requests such permission.
7. Impervious gloves shall be worn whenever hand contamination is likely, and should be seriously considered whenever quantities requiring a radioactive materials area sign are being handled.
   Impervious gloves shall always be worn when handling open vessels containing alpha emitters or Sr-90, or when handling equipment possibly contaminated with these materials.
   Gloves should be cleaned, if practicable, before removal or disposal. They should be handled and stored to prevent contamination of the inside surface.
8. Laboratory coats shall be worn by all individuals handling radioactivity. In cases where millicurie amounts of activity are being handled and there is a likelihood of spillage and personal contamination, the laboratory coat should be removed before leaving the isotope laboratory and kept in the laboratory. It should be monitored for contamination before sending to the laundry.

6.7. Storage

1. Radioisotopes requiring a "Radioactive Materials" label must be stored in areas under the control of the licensee, which may be locked or otherwise secured against unauthorized removal of the material.
2. The radioisotopes shall be stored in a container, shielded if necessary, such that the radiation at a distance of 1 foot from the container does not exceed 100 mrem/hour, i.e., the area may be classified as no more than a radiation area.
3. Containers must be properly labelled and area signs posted where necessary.

4. Suitable precautions shall be taken so that the probability of an explosion in the storage area which would cause the dispersion of the radioactivity is very small.

6.8. **Transportation on Hospital Premises**

1. Radioisotopes requiring a "Radioactive Materials" label must be enclosed in nonshatterable carrying cases or containers, preferably metallic, before being transported through corridors or between buildings.
2. Containers for the transportation of beta sources requiring a "Radioactive Materials" label must provide shielding thicker than the maximum range of the beta rays.
3. Gamma ray emitters shall be transported in closed containers, shielded if necessary, such that the dose-rate at the surface does not exceed 200 mrem per hour, and the dose-rate at one meter does not exceed 10 mrem per hour. (This rule follows the ICC shipping regulations.)

6.9. **Radioactive Waste Disposal**

6.9.1. **Storage of Wastes**

a. Each laboratory should maintain a metal waste can with a foot-operated lid, which must display a radioactive materials label in a prominent position. The use of a disposable liner is recommended in order to maintain the waste can free of contamination. Where there is a large turnover of waste, it is advantageous to maintain separate cans for combustible and noncombustible or reclaimable materials. Combustible wastes in the laboratory should be held to a minimum.

b. Radioactive wastes must be stored only in restricted areas where they can be secured against unauthorized removal.

c. Waste that contains short-lived radioactive material should be stored temporarily in a marked area to permit substantial decay before ultimate disposal.

d. Liquid wastes should be stored in unbreakable containers, preferably in polyethylene bottles. There must be no possibility of a chemical reaction during storage that might cause an explosion or cause the release of radioactive gases or vapors. Liquids shall be neutralized before deposition in a waste container.

6.9.2. **Liquid and Gaseous Wastes**

An authorization for the use of isotopes may contain limitations on disposal of liquid wastes by sink and of gaseous wastes through hoods. Instructions for record keeping may also be given. Such limitations will be designed to insure conformity with Federal and State regulations.

Any laboratory, however, may dispose of radioactive waste into a designated sink if the following conditions are met:

a. A record is kept giving the date and upper and lower limits to the amount of activity discharged for the day.

b. The material is readily soluble or dispersible in water.

c. The quantity of material discharged per day into the sink does not exceed the minimum amount requiring a radioactive materials label (table II, col. II).

The Radiation Safety Officer must be consulted for daily disposal of larger quantities than the minimum amount requiring a radioactive materials label.

The foregoing restrictions do not apply to excreta from individuals undergoing medical diagnosis or therapy with radioactive materials. However in the case of therapy with large quantities of radioactive iodine (>30 mc), the urine shall be collected and stored in a shielded area for at least 6 weeks before disposal into a toilet. Following disposal, the toilet shall be flushed with a large quantity of water.

6.9.3. **Solid Waste**

Solid wastes with long half lives shall be placed in metal cans, marked with the radiation symbol and designed for the purpose. These cans are obtainable from the MGH Hot Laboratory. They will be packaged periodically under supervision of the MGH Hot Laboratory for disposal via a commerical service for a fee chargeable to the licensee.

6.9.4. Incineration.

Incineration by users is allowed only where specific permission is granted on the license. Incineration will be performed under the control of the Radiation Safety Officer, and will be permitted only for well-defined limits of activity for specific isotopes.

6.10. Design of New Facilities

The design of all facilities involving the use, handling or storage of radioactive materials shall be reviewed by the Radiation Safety Officer to assure the maintenance of adequate environmental protection.

7.0 ANIMALS CONTAINING RADIOACTIVE MATERIALS

7.1. Injections of radioactive materials in animals shall be carried out in stainless steel trays having absorbent materials in the bottom. Rubber surgical gloves shall be worn by the worker, for all levels of radioactivity requiring a radioactive materials sign.

7.2. All cages housing animals injected with radioactive material shall be clearly marked as follows:

a. Name of the radioisotope
b. Amount of radioactive material injected per animal
c. Date of injection
d. Principal investigator's name
e. "Caution Radioactive Material" tape must be affixed to the cage.

7.3. Animals containing radioactive materials must be kept in cages apart from other animals.

7.4. All animal excreta which may contain radioactivity shall be collected and disposed of, if necessary after storage. There are no restrictions for disposal through the sewage system if the excreta is in a suitable form—i.e., not mixed with sawdust or wood shavings.

If the excreta shows no significant activity above background when monitored by a survey meter appropriate to the radioisotope involved, it may be discarded with normal trash in a suitable container.

In all other cases, the excreta shall be labeled with the name of the isotope and the estimated amount of activity, and either incinerated or stored prior to shipment via a commercial disposal company, in accordance with the rules for disposal (see. 6.9.1.).

7.5. The carcasses or dissected parts of injected animals shall be wrapped in absorbent material a id placed in a watertight container so as to prevent dripping during transportation from one area to another.

7.6. Adequate ventilation and air cleaning must be provided in instances where animals are stored after an injection of radioactive materials that may be volatilized and dispersed in the room.

7.7. No incineration can be permitted without a specific license. All incinerations of carcasses must be carried out in the incinerator of the Research Building. The incinerator operator must first receive approval to incinerate from the Radiation Safety Officer. All radioactive material for incineration shall be labelled with isotope, quantity and date measured.

7.8. Animals placed in a refrigerator prior to incineration or other disposal must be properly labelled.

8.0 HUMAN USE OF RADIOACTIVE MATERIALS

In evaluating proposals for the human use of radioisotopes, the Isotope Committee will be guided by the following statement of policy accepted by Harvard Medical School.

8.1. Internal Beta-Gamma Emitters

Tracer doses in humans shall be kept to the lowest practicable level.

Adult humans who are ill and who are expected to receive benefit from a diagnostic procedure involving the administration of radioactive materials shall not ordinarily receive amounts such that the total absorbed dose exceeds 10 rad in any 12-month period. Children in this category (all patients below 15 years of age) shall not receive more than a total absorbed dose of 1.0 rad. The cumulative dose absorbed as a result of such procedures shall not exceed 5 rad before age 15, or 20 rad before age 30. Dosage calculations shall be made for the organ of maximum dose as shown in the appendix 4.

When volunteers who are not ill are given tracer doses, the amounts must be limited such that the total absorbed dose does not exceed 2.5 rad for adults or 0.25 for children in any 12-month period. The cumulative dose shall not exceed 2.5 rad before age 18 and 10 rad before age 30. Whenever possible, volunteer subjects should be at least 30 years of age.

On the basis of considerable clinical evidence, a larger dose can be permitted for the thyroid gland. So long as no other part of the body receives more than the limits as stated, an increase by a factor of 25 is allowed for the thyroid. Similarly a factor of two is allowed for the skin in accord with the recommendations of the National Council on Radiation Protection.

Examples of the critical organ doses per millicurie administered and of the maximum amounts of radioactive isotopes that may be administered to an adult volunteer are presented in appendix 4 in μc/gm for many important radioisotopes.

8.2. External Beta-Gamma Emitters

If the absorbed doses are maintained at levels not exceeding those stated in 8.1, the exposures will generally be approved by the Isotopes Committee.

8.3. Internal Alpha Emitters

Since alpha emitting isotopes are particularly hazardous, special consideration must be given by the Isotopes Committee when alpha particles are to be administered to humans.

8.4. Special Cases

It is recognized that some procedures require doses larger than the limits set forth above. In cases for which the expected benefits are considered to justify doses, permission may be granted by the Committee.

9.0 Nursing Care of Patients Receiving Radioactive Materials

Hazards of Radioactive Isotopes

Hazards may arise from three sources:

1. Contamination of the skin with radioactive materials.
2. Inhalation or ingestion of radioactive materials in the body.
3. Irradiation of the body from outside by radiations emitted from these materials.

No precautions are usually needed for those patients who have received tracer doses of radioactive materials for *diagnostic tests*.

In general, precautions should be taken when doses of radioactivity above 1 mc (millicurie) are used.

The hazards increase with increased level of the dose.

Information about special hazards should be obtained from the physician responsible for the administration of the radioactive material.

General Principles of Protection

1. Skin contamination, ingestion, or inhalation is prevented in part by practicing good housekeeping, hand washing, and clean work habits.
   a. Radioactive materials should not be allowed to come into contact with the skin.
   b. Where radioactivity is present, personnel should not be allowed to eat or smoke.
   c. Monitoring, i.e., checking equipment or work areas for radioactivity with a geiger counter, is necessary when contamination is suspected. (Call extension 2511, 2429, Radiation Safety Officer.)
2. External irradiation of the body may be reduced to permissible limits by:
   a. Taking precautions in handling contaminated equipment.
   b. Spending the minimum of time close to patients with therapeutic doses of radioactivity.

General Precautions

1. The length of time personnel should remain at any particular distance from the patient shall be determined by the doctor.
2. Wash hands after contact with patient. Give particular attention to fingernails. Avoid working with open cuts.
3. The RSO (extension 2511) shall be informed if articles are likely to be contaminated. If the RSO is not immediately available, the articles shall be stored in a metal container (e.g., trash barrel) to be provided by the Building Service, and will be monitored later by the RSO.
4. It is not necessary to limit visitors in general. In circumstances where very large doses are used and there may be possible contamination, limitations shall be specified by the doctor. (See especially the rules for Radium.)

9.1 Nursing Care for Patients Receiving Tracer Doses of Isotopes Internally for Diagnostic Studies

General Principles

1. There is no danger in carrying out routine nursing care.
2. Patients are allowed visitors in accordance with the usual hospital rules.
3. Precautions may be necessary if urine or stools are to be saved for isotope studies. Special orders will be written as indicated.
4. If the patient should vomit within the first few hours of oral ingestion of radioisotopes, call the responsible physician. (See below for special instructions concerning vomitus.)
5. No special precautions are needed for dishes, instruments, or utensils.

Special Instructions

1. If there are any special instructions for a particular case, they will be noted on the patient's order sheet.
2. When cleaning up vomitus or handling contaminated articles, the nurse or aide should wear rubber gloves. The R.S.O. should be called for disposal of contaminated paper towels or other articles. These articles should be set aside to await his arrival and should *not* be disposed of by routine methods.

9.2 Nursing Care of Patients Receiving Radioactive Iodine

General Principles

1. Radioactive iodine is administered orally. That portion of the dose which is not retained by the thyroid is almost entirely excreted in the urine.
2. Precautions which must be taken depend entirely upon the amount.
3. Except under unusual conditions (see below), routine nursing care may be employed, and patients may be allowed visitors in accordance with usual hospital regulations. The patient need not be in a single room.

Detailed Instructions for General Nursing Care

1. No precautions whatsoever are needed for patients who have received doses of radioactive iodine for diagnostic purposes, except when vomiting occurs *within the first hour* of administration. (See special instructions in previous section.)
2. Patients who have received therapeutic doses for thyrotoxicosis or for heart disease do not need to be isolated from the nursing staff, visitors, or other patients.
3. Patients who have received *very large doses* [3] of radioactive iodine for the treatment of cancer will have special precautions posted and special instructions given at the time of treatment. The following rules generally apply in these cases:
   a. Visitors should be limited to *no more than 1 hour per day per visitor*, unless approval for longer visits has been obtained from the responsible physician.

[3] 30 millicuries or more.

b. Nursing personnel should attend the patient for routine purposes, but if special nursing care is required, the problem of nursing exposure will be worked out by the Radiation Safety Officer in collaboration with the Thyroid Group.

c. The nurses in attendance should secure and wear a film badge. These may be obtained from the Radiation Safety Officer (extension 2429 or 2511) and will be collected monthly. A badge shall be worn only by the nurse to whom it is issued and shall not be exchanged between nurses.

Excretions

Use rubber gloves whenever handling excretion of a patient or contaminated materials.

A. *Urine*

1. Urine should be collected when requested directly via funnel into the bottle provided which is kept in a lead cart at the bedside. This urine will be disposed of by the Thyroid Group.
2. A balloon catheter may be inserted in the bladder before treatment.
3. In cases where urine is not to be retained, it may be disposed of in the usual way, taking care not to spill.
4. Any spillage should be immediately and thoroughly wiped with paper towels which should be placed in the marked radioactivity disposal can.
5. Encourage the patient to take care of his own collection if possible.

B. *Stools*

Usually there is very little radioactivity in stools. They may be disposed of in the usual way, unless retention is requested.

C. *Sputum and Vomitus*

1. Should the patient vomit during the first 48 hours *after therapy*, the vomitus (and sputum) should be collected in a waterproofed cardboard container and saved within the lead cart. It must be sent to the Thyroid Laboratory for assay. It should be labelled with the name of patient, date and time of vomiting.
2. If the vomitus is spilled it should be wiped up with towels by a nurse wearing rubber gloves. All linens soiled by vomitus and contaminated rubber gloves should be deposited in the lead cart (for urine storage).

D. *Soiled Tissues and Sponges*

Place soiled tissues and sponges in a paper bag attached to patient's bed. This should then be transferred to the disposal can on the floor.

E. *Incontinence*

If there has been a large spill of urine or vomitus, notify the doctor. *Do not handle the damp bed clothes* without rubber gloves. Remember *distance, heavy metal shielding,* and *short exposure times are the best methods of protection.*

Equipment

1. A metal can [4] with laundry bag inside should be provided to collect linen where there is possible contamination by Iodine-131. The disposal of possibly contaminated linen should be determined by the monitoring service (extension 2511 or 2429).
2. A disposal can suitably marked for radioactivity [4] should be placed on each floor with I–131 therapy cases to collect active waste. This will be emptied periodically by the Thyroid Group (extension 334).
3. Heavy rubber gloves from the pharmacy should be worn while cleaning contaminated equipment. These gloves should be washed with soap and running water while on the hands and dried before removal. Gloves should be monitored periodically by the monitoring service (extension 2511, 2429) who will dispose of them, if necessary.
4. A designated sink on the floor should be used for washing contaminated equipment. This sink should be washed after each use with soap and water and scrubbed with a brush to prevent collection of radioactivity and subsequent dissemination.
5. Thoroughly wash with soap and running water, items such as bed pans, urinals, and basins. Use items for same patient until treatment is complete. Have this equipment monitored (extension 2511, 2429) before it is used for other patients.

Bath

Unless specifically ordered by the doctor, the bath should be postponed for the first 48 hours.

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[4] Secured from the Thyroid Laboratory.

Emergency Situations

If there are any questions of contamination, techniques for handling contamination, or personnel exposure, a member of the Thyroid Group (extension 334) or the Radiation Safety Officer (extension 2511, 2429) should be contacted.

9.3 Nursing Care for Patients Receiving Radium Therapy or Cobalt Needle Therapy

General Principles

1. All patients receiving radium or cobalt therapy must have a yellow radiation tag on their wrist which may *only* be removed by the attending physician or the radiologist when the radium or cobalt is removed from the patient.
2. The patient's bed must be isolated from other patients (see below for rules).
3. Nurses should spend only the necessary time near a patient for routine nursing care but must obtain and wear a film badge (see below).
4. Visitors must be restricted in accordance with the rules below.
5. No special precautions are needed for sputum, urine, vomitus, stools, dishes, instruments, utensils or bedding unless specifically ordered.

Special Instructions

A. *Patients*

1. These patients must stay in bed unless orders to the contrary are written.
2. If a patient is in an individual room, the bed must be arranged so that there is at least 6 feet distance to occupied beds in neighboring rooms.
3. Patients in semiprivate rooms or on a ward should be allocated an isolated or corner bed if possible. The *minimum* clear space between neighboring beds must be 6 feet. The minimum distance between the feet of beds on opposite sides of a ward must be 4 feet.
4. Women of child-bearing age should not be allocated to beds next to a radium patient.

B. *Nursing Care*

1. Never handle needles, capsules or plastic boxes containing radium or cobalt with hands. Use long forceps, preferably 12 inches.
2. While the radium is in place, nurses should spend only the minimum amount of time near the patient necessary for routine nursing care.
3. Bed baths given by the nurse should be omitted while the radium is in place.
4. All nurses involved in the personal care of a radium patient should wear a film badge at waist level. When a nurse receives an assignment to a radium patient, the film badge should be procured immediately from the Radiation Safety Officer, extension 2429 or 2511. The badges will be collected and replaced monthly. A badge shall be worn only by the nurse to whom it is issued and shall not be exchanged between nurses.
5. Pregnant nurses should not be assigned to the personal care of radium patients.
6. Perineal care is not given during gynecologic treatment; the perineal pad may be changed when necessary, unless orders to the contrary have been written.
7. Surgical dressings and bandages used to cover the area of needle insertion may be changed only by the attending physician or radiologist and *May Not Be Discarded* until directed by the radiologist. Dressings should be kept in a basin before disposal by routine methods.
8. Special orders will be written for oral hygiene on patients having radium or cobalt therapy to the oral cavity.

C. *Visitors*

1. A visitor may stay at the bedside for *no more than 1 hour per day.* Visitors are not allowed to sit on the bed.
2. Visitors staying for more than 1 hour per day must stay *at least 4 feet from the edge of the bed.*

D. *Emergency Situations*

1. If the radioactive needles, capsules, or plastic boxes become loose or fall out, call the Radiologist (or the Radiology Resident on Call), extension 2393 (days) or 2520 (nights, weekends, holidays).

9.4 Nursing Care of Patients Receiving Radioactive Gold (or Chromic Phosphate) in the Pleural or Peritoneal Space

General Principles

1. Every patient *must* have a yellow *Radiation* tag on his wrist when he returns to the floor after receiving radioactive gold. This tag may *Only* be removed by the radiologist. Special instructions for this patient's care will be written on the order sheet as indicated.
2. The radiologist inserts radioactive liquid through a trochar into the pleural or peritoneal space, and the puncture wound is sutured. Therefore, contamination is not a problem—*unless there is drainage from the puncture wound.*
3. The patient's bed must be isolated from other patients as described below.
4. Nurses should spend only the necessary time near a patient for routine nursing care, but must obtain and wear a film badge (see below).
5. Visitors must be restricted in accordance with the rules below.
6. No special precautions are needed for vomitus, sputum, urine, stools, or dishes.

Special Instructions

A. *Patients With Radioactive Gold*

1. If a patient is in an individual room, the bed must be arranged so that there is at least 6 feet distance to occupied beds in neighboring rooms.
2. Patients in semiprivate rooms or on a ward should be allocated an isolated or corner bed if possible. The minimum clear space between neighboring beds must be 6 feet. The minimum distance between the feet of beds on opposite sides of a ward must be 4 feet.
3. Women of childbearing age should not be allocated to beds next to a radiogold patient.
4. These precautions are not necessary for patients with radioactive chromic phosphate.

B. *Nursing Care*

1. Surgical dressings and bandages may be changed only as directed by the radiologist. If there is no drainage from the puncture wound, dressings may be handled in the usual manner after the first 2 or 3 days. Surgical dressings used over the puncture wound during the first few days may not be discarded until directed by the radiologist. (See "Emergency Situations" below.)
2. Bed baths given by the nurse should be omitted for the first 48 hours, unless specially ordered.
3. Bedding may be changed as usual unless there has been drainage from the puncture wound, in which case the radiologist should be notified and he will direct the disposal of the soiled bedding. (See "Emergency Situations" below.)
4. All nurses involved in the personal care of a radiogold patient should wear a film badge at waist level. When a nurse receives an assignment to such a patient, the film badge should be procured immediately from the Radiation Safety Officer (extension 2429 or 2511, White 2). The badges will be collected and replaced monthly. A badge shall be worn only by the nurse to whom it is issued and shall not be exchanged between nurses.
5. Pregnant nurses should not be assigned to the care of a radiogold patient.
6. Rules 2, 4, and 5 do not apply to the use of radioactive chromic phosphate.

C. *Emergency Situations*

1. If there is any question of contamination of bedding, furniture, instruments, clothing, floor, utensils, etc., immediately call the RSO, as noted below, who will monitor the area for radiation hazards and determine what protection or disposal methods are indicated.

2. If the surgical dressing becomes damp or bloody because of drainage or leakage from the puncture wound, *Do Not Touch the Dressing* but call the attending physician or radiologist. Keep all wet dressings removed (together with all instruments or utensils used) in a Dressing Basin on the patient's bed or table and *Do Not Discard* until so directed by the radiologist.
3. The radiologist (*or radiology resident on call*) may be reached at extension 2511.

9.5 Nursing Care of Patients Receiving Radioactive Phosphorus in Therapeutic Doses

General Principles

1. If the P–32 (radioactive phosphorus) is given intravenously, there is no radiation hazard near the patient and no special precautions are necessary.
2. If the P–32 is given orally, there is no radiation hazard unless the patient vomits the first 12 hours. If the patient vomits during the first 12 hours, follow the instructions given below under "Special Instruction," paragraph No. 2.
3. Nurses may spend whatever time necessary near a patient for routine nursing care.
4. Patients are allowed visitors in accordance with the usual hospital rules.
5. No special precautions are needed for sputum, stools, dishes, instruments, or bedding. See below ("Special Instructions," paragraph No. 2) for precautions to be used for vomitus. Urine is usually radioactive and should be handled with care, using rubber gloves. (See paragraph No. 3 below).

Special Instructions

1. If the P–32 has been given intravenously, and the patient vomits, no special precautions are necessary.
2. If the P–32 has been given orally and the patient vomits within 12 hours, the vomitus and any soiled clothing, bedding and utensils should be collected and put into any available covered metal can which should be labelled "Radioactive." Wear rubber gloves to do this, and then still wearing the gloves, wash them with soap and water at any sink. Use plenty of water to wash down the sink. Place the gloves after removal with other contaminated items. Call the radiologist (*or radiology resident on call*) who will arrange for the disposal of the contaminated items. (See "Emergency Situations" below.)
3. If a urinal or bedpan is used, care should be taken to avoid spillage in transferring urine to the toilet. *Rubber gloves* are advised when handling urine. If urine collection has been ordered, carefully transfer it to a 5-pint bottle. The bottle should be labelled with the patient's name, number, and time of collection and sent to the ordering physician. Urine spillage should be wiped up with paper tissues and these may be flushed through the nearest toilet. Gloves should be thoroughly washed with soap and water while still on the hands and then disposed of in the usual way. Likewise the urinal should be thoroughly washed at any sink before re-use.
4. If the P–32 is used topically (direct application to the skin under a surgical dressing) *do not touch* the dressing. If the dressing becomes loose or needs changing, call the radiologist or the radiology resident on call, as noted below.

Emergency Situations

1. In case of loose dressings or any problem or question not answered above, call the radiologist (or the radiology resident on call), extension 2511.

10. SAFE HANDLING OF CADAVERS CONTAINING RADIOACTIVE ISOTOPES

10.1. Procedure After Death of Patient

10.1.1. If a patient containing less than 5 mc of radioactive material dies in the Hospital, no special precautions are necessary.

10.1.2. If a patient dies in the Hospital and contains more than 5 mc, the doctor signing the death certificate should inform the pathologist and the RSO of this fact. The funeral director's form should be completed (app. 5).

If there is an autopsy, it may be necessary for the pathologist to take precautions detailed in 10.2 while performing the autopsy.

If there is no autopsy and the body contains more than 30 mc, the doctor signing the death certificate should notify the RSO who will prepare a statement for the funeral director.

10.2. **Conduct of Autopsy**

1. When a cadaver suspected to contain more than 5 mc of radioactive material is to be autopsied, the RSO should be notified.
2. The amount of activity remaining in the body should be estimated by reference to the time elapsed since the administration of the isotope and its biological fate.
3. If the remaining amount is less than 5 mc, no special precautions are necessary other than the usual wearing of gloves, except in cases of I–131 therapy, where the handling of the thyroid gland which contains most of the activity should be minimized.
4. Where the residual activity exceeds 5 mc, the following procedures should be followed:
   a. Survey the body before it is opened to establish maximum working times if necessary.
   b. Drain carefully all body fluids and save for assay. In cases of I–131 therapy, the blood and particularly the urine will be radioactive
   c. After the body is opened, a second survey should be made to estimate levels of beta-ray dose, particularly in the pleural or peritoneal cavity following treatment with Gold-198.
   d. Where intense beta ray fields exist (e.g., from Gold-198) the use of double gloves will significantly reduce the hand-dose. The working time inside the body will usually be limited by the acceptable exposure of the hands of the pathologist. The use of goggles or glasses is also recommended.
   e. In cases of I–131, the thyroid gland will produce a gamma ray dose of about 0.5 r/min near its surface for each 10 mc in it, and consequently should not be touched by hand directly. Its removal, depending on the activity level, should be accomplished using long instruments.
5. Highly radioactive fluids should be stored behind a shield before disposal via the sewage system (see sec. 6.9.2). Highly radioactive specimens should also be stored and handled as infrequently as possible until levels of a few millicuries are reached.
6. All instruments and clothing involved in the autopsy should be monitored after the procedure and stored or decontaminated before return to general use or despatch to the laundry. The autopsy room should also be surveyed and decontaminated if necessary.

10.3. **Precautions Regarding Embalming**

1. A radioactivity form should be filled out if the residual activity exceeds 5 mc (app. 5).
2. A body containing less than 30 mc may be released directly to the funeral director for embalming without the advice of the RSO, and the form should indicate that no precautions are necessary for standard embalming procedures.
3. The RSO should recommend precautions, if necessary, on the form accompanying a body containing more than 30 mc. Such precautions might include the wearing of rubber gloves by the embalmer, and the removal of body fluids into a closed system avoiding spillage.

11. EMERGENCY PLANS

11.1. **Sealed Source Rupture**

If a disruption of a sealed source occurs, or if potentially hazardous quantities of radioactive dusts, mists, fumes, organic vapors, or gases are introduced into the air, the following emergency measures should be taken immediately:

1. No immediate attempt should be made to clean up the spill.
2. All windows should be closed, fans and air-conditioners should be shut off, and everyone should leave the room.
3. All doors should be closed and locked.
4. If powdered or gaseous sources are involved, the door and all other openings leading into the room should be sealed with wide masking tape or adhesive tape and heavy wrapping paper.
5. The spread of radioactive contamination can be diminished by restricting the movements of potentially contaminated persons to a local zone just outside the spill area until the extent of shoe and clothing contamination is ascertained.
6. Every person who might have been contaminated should be monitored for radioactivity, and, if contaminated, should remove his clothes and be decontaminated. If no means are available for monitoring, it should be assumed that the person is contaminated.
7. The Radiation Safety Officer should be immediately called. If necessary, outside consultants experienced in radiation hazards should be called in and their advice followed.

11.2. Radioactive Liquid Spills

All spills of radioactive material must be cleaned up promptly. The responsibility for cleaning or for calling for experienced help rests on the individuals working in the area involved and responsible for the spill.

Under no circumstances should any untrained person attempt to examine or clean up a *major* spill of radioactive material. (The cleanup technique should be planned with the same care as is used in quantitative chemical analyses or in bacteriological handling of virulent organisms). Fans or ventilating apparatus should not be turned on in an attempt to blow the isotope or its decay products away. Such a maneuver will only disseminate the radioactive material throughout the area. If the isotope is blown out of a building, air currents may carry the finely divided material into nearby windows or air-intake ducts. Proper precautions taken immediately will protect human life and reduce financial losses.

The Radiation Safety Officer shall be notified immediately of all accidents involving *possible* body contamination or ingestion of radioactivity by personnel, overexposure to radiation, contamination of equipment, spread of contamination or difficulty in cleaning up a contaminated area. The RSO must be notified immediately in the event of loss of radioisotopes.

The following procedures will be followed:

A. *Minor Spills*

1. Notify all persons in the room at once.
2. Permit only the minimum number of persons necessary to deal with the spill in the area.
3. Confine the spill immediately.
4. Don protective gloves and drop absorbent paper on the liquid spill.
5. Decontaminate, using a monitor to check the progress of the work.
6. Monitor all persons involved in the spill and the cleaning.

B. *Major Spills*

1. Notify all persons not involved in the spill to vacate the room at once, and notify the Radiation Safety Officer.
2. If hands are protected from contamination (i.e., gloves) right the container of the spilled liquid.
3. If the spill is on clothing, discard outer clothing at once.
4. Vacate the room.
5. Take immediate steps to decontaminate involved personnel.
6. A consultant experienced in radiation hazards should be called in and his advice followed.

NOTE: Special problems associated with the spillage of liquid sources are covered in NBS [National Bureau of Standards] Handbook 48, pp. 20 and 21.

ADDITIONAL READING

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LABORATORY

David F. Burgoon

CONTINUAL EXPOSURE to actual and potential hazards involving the health and safety of personnel is inherent in a laboratory environment. This can be reduced to some degree by training technical staff in the proper handling of laboratory equipment, chemicals, and reagents. However, laboratory personnel must be reminded constantly of the fundamentals of laboratory safety, to which good sanitation is basic in providing a safe and healthy environment. The achievement of this goal can be assured by the establishment of a dynamic program of laboratory sanitation and safety. The program criteria should include:

1. Management support with adequate financial backing;
2. Qualified leadership with full responsibility for program;
3. A program organization designed to carry out functional areas of responsibility;
4. An adequate supervisory and operational staff in the laboratory;
5. A planned training program designed to meet changing concepts of methods and techniques;
6. Equipment, supplies, and materials which will achieve the established standards of sanitation and safety; and
7. Utilization of laboratory facilities and professional talent to measure the degree of sanitation and safety.[1]

LABORATORY SAFETY COMMITTEE

The laboratory service, because of sanitation and safety problems related to its particular working environment, should establish a Laboratory Safety Committee.[2] The committee may vary in size according to the organizational structure of the laboratory service. If the service is departmentalized, it might be well to have a representative from each laboratory section and worker classification. Members of the committee should be chosen on the basis of their interest in safety and for their leadership ability. Meetings are usually scheduled once a month or more often for special circumstances requiring action.

The chairman of the committee also should be appointed to the hospital Sanitation and Safety Committee as the laboratory representative. Such representation would provide necessary liaison between the two committees.

Committee Functions

The laboratory safety committee should perform the following functions:

1. Formulate safety recommendations;
2. Recommend purchase of safety equipment and suggest any necessary physical changes to improve safety conditions in the laboratory;
3. Prepare a sanitation and safety manual for the laboratory;
4. Coordinate program with other elements of the environmental program in the hospital;
5. Maintain duplicate copies of reports of all accidents occurring to laboratory personnel;
6. Review all accidents which occurred in month prior to monthly meeting;

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7. Prepare a summary of accident statistics for safety operations, using a monthly or yearly base line;

8. Keep charts and graphs of accident incidents and types, and post or distribute these to stimulate workers to a better record;

9. Post or distribute committee minutes.

The committee sponsors demonstrations of equipment and protective clothing; develops rules for personal hygiene and personal practices, handling of glassware and electrical equipment; develops procedures to report accidents, illness, fires, explosions and spillage and suggests safe methods of waste disposal and cleaning. A laboratory sanitation and safety manual should describe in more detail how types of equipment are used and what laboratory procedures require their use.

EQUIPMENT

Personnel concerned with environment in hospitals are able to perform more effectively if they are aware of laboratory hazards and the equipment used to overcome or reduce them. Many items of laboratory safety equipment are designed to reduce injury or illness to personnel performing procedures involving infectious, toxic, poisonous, explosive, or flammable material. Protective equipment should be provided and personnel should be instructed in when and how to use it. Good supervision will also insure that personnel use this equipment properly.

Some of the most necessary items of protective equipment and their use are:[3]

1. Fume hoods—to protect personnel from noxious or toxic odors and flammable or explosive chemicals;

2. Explosion proof refrigerators—to store flammable liquids;

3. Tongs—to handle hot beakers, flasks, casseroles or evaporating dishes;

4. Safety filling device—attachment for pipette used when pipetting poisonous, corrosive, or other harmful liquids;

5. Goggles—to protect the eyes from spattering chemicals and flying particles;

6. Safety glass shields—to protect against liquid and flying glass from possible explosion during distillation procedures;

7. Gas cylinder supports—to secure gas cylinders against being knocked over and causing possible explosion;

8. Safety can for flammable liquids—metal containers for storage of flammable liquids to prevent fire and explosion;

9. Laboratory hand trucks—to provide a safer method for transporting gas cylinders, carboys, and drums;

10. Acid bottle carriers—to prevent spillage and breakage in transporting large volumes of corrosive chemicals;

11. Carboy inclinator—to prevent physical strain, injury, and spillage when filling smaller containers of corrosive and flammable liquids from carboys;

12. Bottle tilter—has the same purpose as carboy inclinator except it is used for containers of 5 gallons or less;

13. Respirator guards—to prevent inhalation of toxic vapors and fumes, dust, and smoke;

14. Gloves and mittens—to protect hands when using hot containers that cannot be handled properly with tongs;

15. Neoprene or rubber gloves—to protect hands when handling large quantities of corrosive and skin-irritating liquids or contaminated material; and

16. Stopcock and bottle stopper remover—to remove frozen stopcocks and bottle stoppers and prevent injury if glass breaks.

Figures 10 and 11 illustrate some laboratory safety precautions.

PROTECTIVE CLOTHING

All personnel performing technical laboratory procedures should wear long-sleeved, knee-length laboratory coats or uniforms. Service personnel should be provided with whatever type of protective clothing is required in their particular job assignments. Coats and uniforms should be kept buttoned and belts fastened at all times. Clothing which has been splashed with corrosive, contaminated, or flammable chemicals or solutions should be changed immediately.

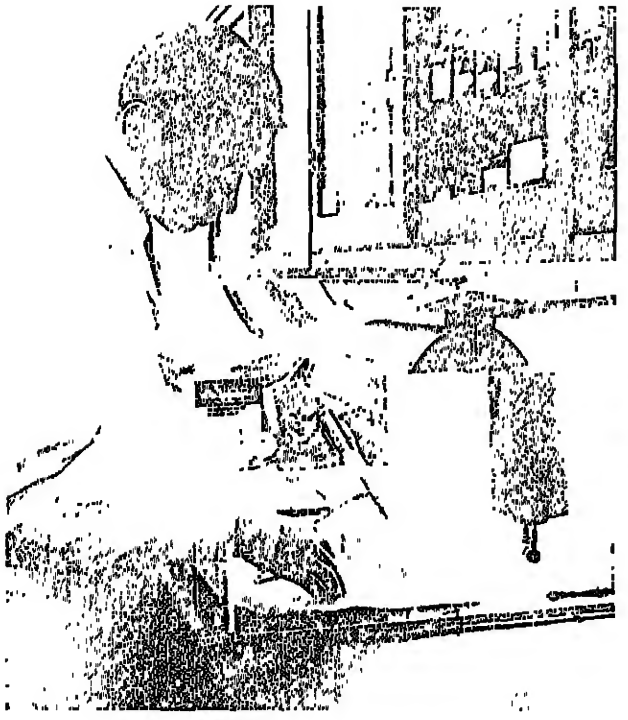

Figure 10. **Safety pipetting equipment and shield minimize chances for accidental infection.**

PERSONNEL PRACTICES

The following summary of laboratory safety procedures appeared in a recent periodical and constitutes a good basic checklist:

The rules and techniques needed to handle pathogenic organisms safely are so varied, depending upon the agent, experiment, experimenter, and equipment, that it is not possible to do much more than refer to a few of the good reviews on the subject.* Each laboratory contemplating formulation of a set of regulations would do well to examine these reviews and then adapt and adopt those that are suitable for the local situation. Some of the laboratory regulations most widely applicable to infectious agents are:

1. There will be no direct mouth pipetting of infectious or toxic fluids.

2. Pipettes will be plugged with cotton.

3. No infectious material will be blown out of pipettes.

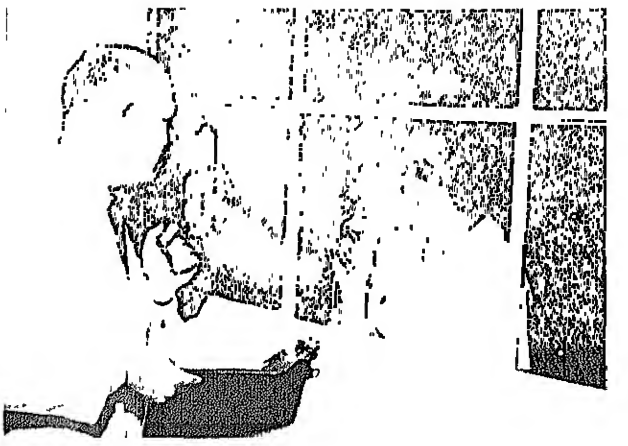

Figure 11. **Separation between area housing inoculated lab animals and other areas should be preserved at all times. Communication speakers permit necessary monitoring of experiments without direct contact.**

4. No mixtures of infectious materials will be prepared by bubbling expiratory air through the liquid by a pipette.

5. Use an alcohol-soaked pledget around the stopper and needle when removing a syringe and needle from a rubber-stoppered bottle.

6. Use only needle-locking hypodermic syringes.

7. Expel excess fluid and bubbles from a syringe vertically into a cotton pledget soaked with disinfectant or into a small bottle of cotton.

8. Before and after injection of an animal, swab the site of injection with a disinfectant.

9. Sterilize discarded pipettes and syringes into the pan into which they were first placed after use.

10. Before centrifuging, inspect tubes for cracks. Inspect the inside of the trunnion cup for rough walls caused by erosion or adhering matter. Carefully remove all bits of glass from the rubber cushion. A germicidal solution added between the tube and the trunnion cup not only disinfects the surfaces of both of these but also provides an excellent cushion against shocks that otherwise might break the tube.

11. Use centrifuge trunnion cups with screw caps or equivalent.

* See "Additional Reading," p. 36.

12. Avoid decanting centrifuge tubes. If you must decant, afterwards wipe off the outer rim with a disinfectant. Avoid filling the tube to the point that the rim becomes wet with culture.

13. Wrap a lyophilized culture vial with disinfectant-wetted cotton before breaking.

14. Never leave a discard tray of infected material unattended.

15. Sterilize all contaminated discard material.

16. Periodically clean deep freeze and dry ice chests in which cultures are stored to remove any broken ampoules or tubes. Use rubber gloves and respiratory protection during this cleaning.

17. Use rubber gloves when handling diagnostic serum specimens carrying a risk of infectious hepatitis.

18. Develop the habit of keeping your hands away from your mouth, nose, eyes, and face. This may prevent self-inoculation.

19. Avoid smoking, eating, and drinking in the laboratory.

20. Make special precautionary arrangements for oral, intranasal, and intratracheal inoculation of infectious material.

21. Give preference to use of operating room gowns fastened at the back.

22. Evaluate the extent to which the hands may become contaminated. With some agents and operations, forceps or rubber gloves are advisable.

23. Wear only clean laboratory clothing in the dining room, library, and so forth.

24. Shake broth cultures in a manner that avoids wetting the plug or cap.[4]

Wrist watches or rings should not be worn when handling infectious materials. Contact lenses should not be worn by laboratory workers since corrosive liquids may splash in the eye, seep behind the lens, and cause serious damage before the lens can be removed.

Figures 12a and 12b illustrate modular cabinets used for safe inoculation of test animals.

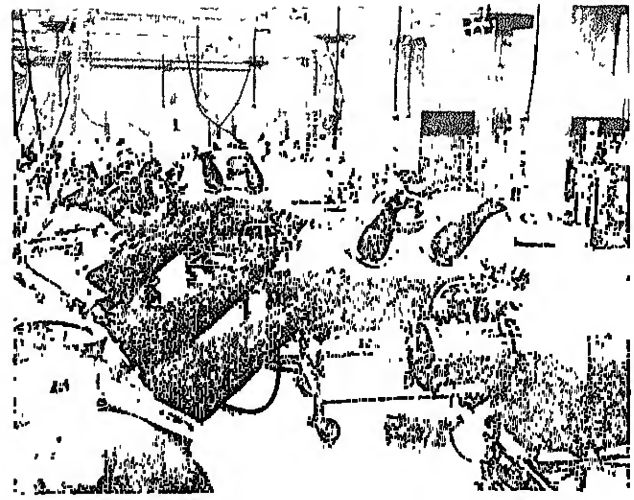

Figure 12a. **Modular cabinets stored in large research hospital.**

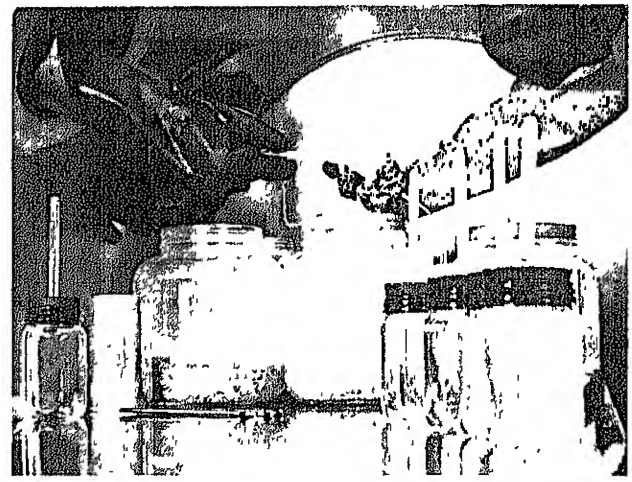

Figure 12b. **Inoculation of test animals with dangerous pathogens is safely done inside modular cabinet.**

Handling of Glassware

A laboratory accident survey conducted during 1956–59 in two hospitals revealed that glass was the number one causative agent in 40 percent of accidents in one hospital and 33 percent in another. The greatest percentage of accidents occurred to the hands, arms, and fingers, accounting for 64 percent in one hospital and 91 percent in another.[5] This survey indicates the importance of orienting laboratory personnel in the proper method of handling glassware. Injuries occur in such procedures as inserting or removing glass tubing from stoppers or rubber tubing; assembling apparatus; removing frozen stopcocks, bottle stoppers, or plungers from syringes; heating and handling large beakers; applying pressure or vacuum to glass containers, and transporting large glass con-

tainers. A bad cut or laceration could result if the glass should break during any of these procedures.

Electrical Equipment

Extreme care must be exercised at all times when using flammable liquids. They should never be used near an open flame or hot plate. Storage of flammable liquids should be permitted only in explosionproof refrigerators. Extension cords should not be used around laboratory workbenches. Good maintenance should be stressed for oven temperature controls to avoid the chance of overheating fire- or explosion-producing material. Continuing inspections are necessary to see that the amount of current and the wiring are adequate to prevent overloading and short circuits of laboratory electrical systems. Frayed and wornout wiring should be replaced immediately.

Waste Removal and Cleaning

To protect nonlaboratory personnel, visitors, and patients when removing hazardous waste material (infectious, corrosive, explosive, or radioactive), laboratory personnel must be trained in the proper handling of such material. The primary responsibility rests with the laboratory supervisor to instruct subordinate personnel in the proper technique for disposing of hazardous material. This may involve instructions to use special types of containers for waste material and to label such material as to type of contamination (for example, infectious or radioactive). Personnel should *not* be assigned to remove laboratory waste materials prior to specific training in the required procedures. Again, detailed procedures in manual form are an invaluable training aid at all levels.

Personnel assigned to cleaning the laboratory should be excluded from areas requiring procedures involving infectious, inflammable, explosive, or otherwise hazardous material. When cleaning any laboratories, they should be cautioned not to touch or handle anything on shelves or workbenches but to clean only the floor surface. The laboratory waiting area for patients, visitors, and other nonlaboratory personnel should be located so as to prevent these individuals from entering laboratory work areas, thus minimizing unnecessary exposure to infection or injury.

ACCIDENT AND ILLNESS

All personnel should be thoroughly indoctrinated in the necessity of immediately reporting to a physician any indication of illness during or after work hours. Burns, cuts, abrasions, or lacerations should receive immediate attention. Immunization programs should be established for all laboratory personnel. All accidents occurring in the laboratory should be reported, whether an injury has resulted or not, so that training programs may be directed toward eliminating any carelessness or neglect by personnel.

FIRES, EXPLOSIONS, AND SPILLAGE

The required number and location of fire extinguishers, escape doors, deluge showers, and eye baths should be given high priority in planning new laboratory facilities. If they are not available in existing facilities, the laboratory safety committee should bring such omissions to the attention of the safety officer or other proper authorities. (See fig. 13.)

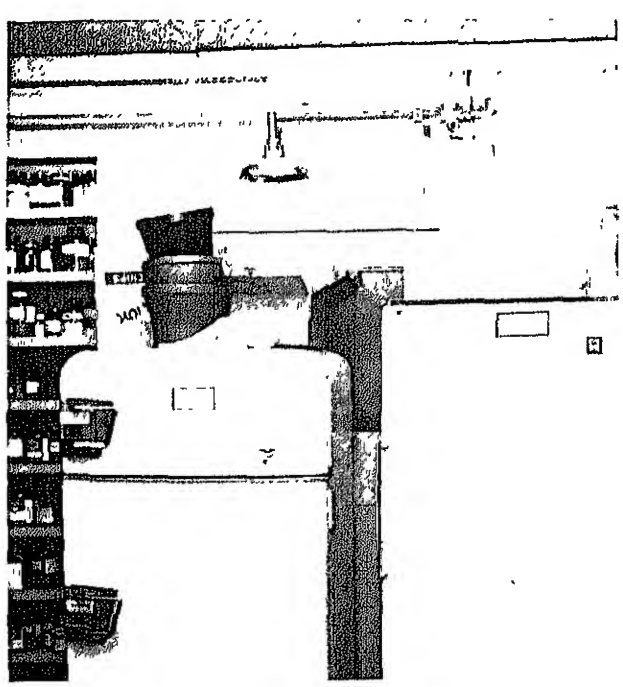

Figure 13. This safety shower in laboratory area is blocked and inaccessible in case of need. Such equipment should always be kept clear and ready for instant use.

ANIMALS

Personnel handling animals inoculated with infectious substances should be properly oriented in procedures to be used to avoid infecting themselves and to prevent the dissemination of infectious organisms. Procedures for the marking of cages, care of infected cages, and the autopsy of infected animals are a few which should be developed.

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FLAMMABLE GASES

Roy Hudenburg

THREE BROAD TYPES of flammable gases are commonly used in hospitals. Cataloged by function, rather than by differences in fundamental characteristics, these are:

1. Domestic heating, including cooking, for which natural gas or liquified petroleum is used;
2. Processing, as in welding operations, for which acetylene gas is used;
3. Medical functions, either treatment or diagnostic, for which gases such as cyclopropane and hydrogen are used.

All flammable gases present similar problems for the administrator. Under proper control and with the operation of adequate safeguards, these gases perform their chores consistently. If through failures of administration, inadequate preventive maintenance, or inadequate employee training, flammable gases mixed with air in the correct proportions are accidentally ignited, a dangerous or fatal explosion may result.

Only through the operation of an adequate Safety Committee, as part of a thoroughly planned safety program, can the administrator protect property and the lives of patients and employees against the consequences of flammable gas explosions.

NATURAL GAS

One common use of gas in the hospital is for the operation of an incinerator. Some hospitals use gas as boiler fuel, or to operate hot-water heating systems. In kitchens, gas is used for ovens and ranges. Two hazards, both linked with gas leaking from pipelines or appliances, accompany the use of natural gas for heating: Infrequently gas may leak from joints in pipes because of vibration or building settlement; or, more often, may leak from joints in newly assembled piping.

The first safety rule in dealing with gas odors is that every employee should be instructed to immediately report any gas leak whenever found. Telephone operators should know how to handle reports of gas leaks, and maintenance employees should be trained in how to proceed. Everyone concerned should be instructed in the importance of keeping flames and sparks out of areas with suspected gas leaks. All maintenance employees should be trained in the technique of hunting for gas leaks using only a brush and soapy water solution.

A great hazard may exist when gas escapes into the atmosphere from an appliance in which a pilot has become extinguished because of low pressure or a breeze. The development of a flammable mixture in the heating section of a hot-water heater or gas oven, and subsequent ignition by a spark, can produce an explosion of tremendous force.

No gas-burning equipment should be installed or remain connected unless it has been fitted with an approved device that automatically closes the gas supply line when the pilot light is extinguished. When there is any doubt about the safe operation of equipment, or its compliance with recognized standards, a thorough check should be made by the local gas supplier.

Standard No. 54 of the National Fire Protection Association, *Standard for the Installation of Gas Appliances and Gas Piping*, provides guidance in the installation and repair of appliances and piping. Standard No. 86 of the NFPA deals

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with large ovens and furnaces. The American Standard Association publication Z-21.33-1950 deals with the installation of gas equipment in large boilers.

LIQUEFIED PEROLEUM GAS

When hospitals are connected to gas mains, they frequently depend on liquefied petroleum gas. This usually involves installation and maintenance of above-ground tanks. Since the flammability limits of both propane and butane gas are low in terms of percentage of gas in air, the chief storage problem of liquefied petroleum gas is the development of pressures within the tank. Therefore, adequate tank pressure release valves are important for safety.

ACETYLENE GAS

Acetylene gas for welding in hospital maintenance operations must be tolerated despite storage hazards and the history of fires associated with inadequate precautions taken during welding operations.

Acetylene is used for welding because it has the greatest flammability of any commercial gas; used with oxygen, it may attain a flame of 6,000°F. Acetylene is unstable under pressure and in its free state is not stored at more than 15 p.s.i.g. Since it is highly soluble in acetone, regulations for commercial shipping require acetylene to be shipped in cylinders containing a porous inert filler and a suitable solvent, usually acetone. It is necessary, therefore, to store and use acetylene cylinders only in an upright position since tilting the cylinder is likely to introduce acetone into the welding flame.

In using oxygen and acetylene in hospital maintenance, a portable rig is usually required. This ordinarily results in a cylinder of acetylene and a cylinder of oxygen being carried on one hand truck, usually two-wheeled, which is parked in an upright position during operation. Safety regulations should require the acetylene tank to be removed from this truck when not in use and stored in a fire-resistant storage room separated from any reducing gases such as oxygen or nitrous oxide.

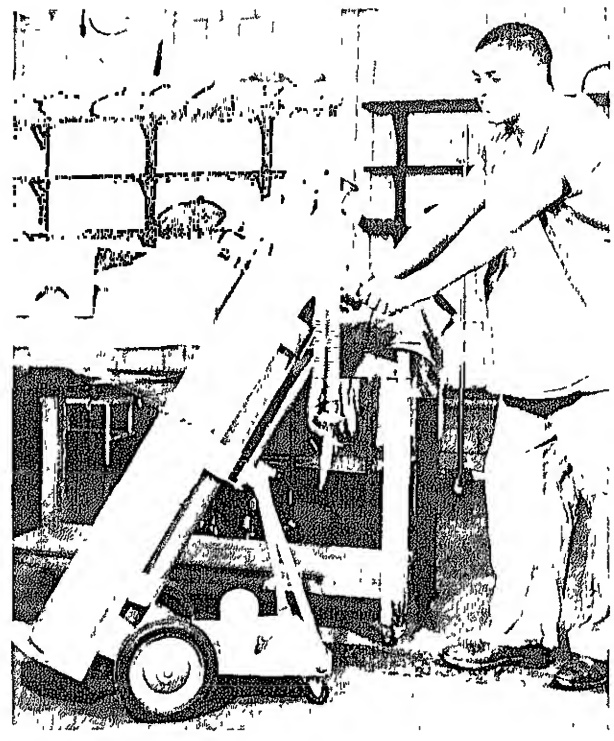

Figure 14. **Proper transporting of gas cylinders to point of use should be entrusted only to trained employees.**

Similar requirements exist for flammable anesthetic gases and reducing agents. (See figs. 14 and 15.)

Despite the generally safe nature of the approved type of cylinder, acetylene gas always should be treated with respect because of its great flammability and instability. Oxyacetylene welding and cutting equipment involves the use of pressure regulators that reduce the pressures of the gases as they leave the cylinder. These regulators, particularly those for oxygen, should never be used unless they are in perfect working condition, and should never be tampered with by hospital personnel. Regulator maintenance should be performed regularly, but only by qualified representatives of the compressed gas companies.

Dangerous fires have occurred in hospitals because oxygen regulators have been tampered with, and there is some feeling that even the grease left from a fingerprint on the regulator diaphragm may sometimes be responsible for fires. Such meticulous precautions are equally necessary for regulators used with medical oxygen.

Hoses and connections used for welding operations should be only those made specifically for

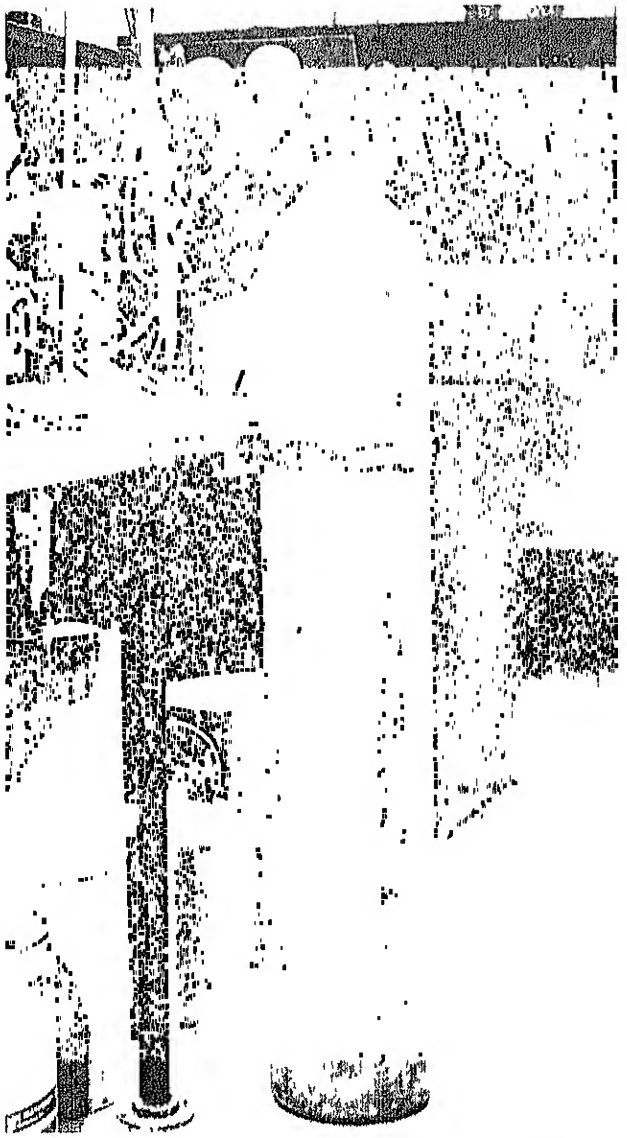

Figure 15. Gas cylinders should be firmly supported at all times.

that purpose. These are color coded, the acetylene hose red and the oxygen line green. Fittings are designed to prevent interchangeability, with left-handed threads on acetylene equipment and right-handed threads on oxygen equipment. NFPA No. 51 provides information on welding hose and connections.

WELDING SPARK FIRES

To safeguard against the hazard of fire from the welding operation itself, hospital safety regulations should require that, whenever possible, material to be welded or cut should be removed to a specially prepared and equipped welding shop. When conditions require welding in place, special precautions must be taken to prevent hot sparks from rolling or flying into combustible material. The greatest hazard accompanies oxyacetylene cutting, in which the acetylene heats the metal and a stream of pure oxygen does the actual cutting.

Fire Protection Handbook (12th edition), published by the National Fire Protection Association, shows that in a cutting operation with correct oxygen pressure hot sparks capable of starting fires may roll as far as 16½ feet from the site of operation. With excessive oxygen pressure they may go even farther. For example, at 70 p.s.i., hot sparks may roll as far as 26 feet and at 100 p.s.i. pressure, as far as 34 feet. This indicates the necessity for moving any neighboring combustible material a substantial distance from the site of the welding or cutting operation or shielding the material with metal screens or asbestos curtains. Care always should be taken to prevent sparks from rolling into recesses or under counters where combustible material may be stored. Welders' torches have been responsible for some of the most disastrous fires of recent years.

Finally, there are hazards in welding operations on tanks or containers that have held flammable liquid. Vapors from such material may remain inside apparently dry containers in the proportion necessary to create an explosive mixture. The only safe procedure is to fill such containers with either water or an inert gas, such as carbon dioxide or nitrogen, to preclude the mixing of air with residual vapors.

Hospital safety regulations for welding should require that a guard or observer accompany the welder during the entire course of a job in any area away from the shop. Welding should always be a two-man operation because the operator must wear dark goggles to protect his eyes against the glare of the flame and particles of flying hot metal and while wearing these goggles he will be unable to see any small fire ignited by flying sparks.

Personnel protection is important, particularly in terms of apparel used during cutting operations. Gloves are required to protect the hands from the heat and some type of flameproofed overall should be worn to protect the body. This covering should be chosen with regard for the severity of the exposure. There should be no open pockets,

cuffs, or closures that gape and permit sparks to enter. An asbestos apron may be required for some kinds of protection, and flame-resistant duck may also be used. A shield with dark lenses that extends over the entire face is preferable to using goggles alone for protection.

MEDICAL GASES

Gases administered to the patient are usually classified as medical gases. For safety reasons, flammable gases should be used only when satisfactory medical results cannot be obtained with nonflammable materials.

Occasionally, new procedures introduced by the medical profession involve use of flammable gases when inert gases might accomplish the same result. Such a situation occurred about 1961 when a procedure was developed for measurement of blood circulation. Hospital safety authorities noted that hydrogen, the most flammable of gases, was being administered to patients. The patients would take one deep breath of hydrogen and the time required for the blood to carry the hydrogen from the lungs to a specified part of the body would be measured. This measurement provided a circulation rate. There was little danger to the patient in the minute amount of hydrogen administered, but there was substantial danger surrounding the storage of the necessary hydrogen tank. Accidents might occur that could be best prevented by keeping the hydrogen off hospital premises. There was no particular reason for choosing hydrogen since an inert gas such as helium could have served as well as the highly flammable hydrogen. (See fig. 16.)

A similar problem is encountered in the operation of the flame photometer. For consistent results, the flame photometer requires use of fuel gas at a constant pressure. Natural gas or liquified petroleum gas, when provided at a constant pressure, is satisfactory. Either of these gases has a safe flammability rating for piping through buildings. Hydrogen, because of its flammability, should never be piped through a hospital building. Nevertheless, demands are sometimes made that hydrogen be provided as fuel for a flame photometer. To add to the hazard, it is often piped in from a site outside the laboratory.

The only way to prevent unnecessary use of flammable gases is through an administrative regulation providing that any order for flammable gas, or for equipment intended to be operated by flammable gas, when purchased for the first time (not repeat orders), must be submitted by the purchasing agent to the hospital Safety Committee for clearance. Investigation can then indicate whether there is a suitable noncombustible substitute or whether adequate safeguards can minimize the hazards of using a flammable gas.

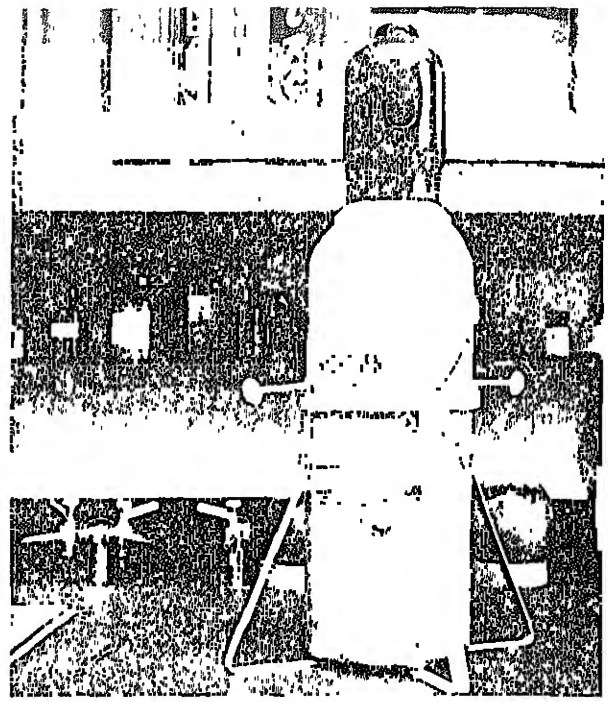

Figure 16. **Proper handling of flammable gases reduces risks in laboratory areas as well as anesthetizing locations.**

Anesthesia Gases

Two flammable hydrocarbon gases, ethylene and cyclopropane, have been used in anesthesia for over 30 years. Nitrous oxide, another anesthetic gas in common use, is capable of supporting combustion but is not flammable. Formerly, ethyl ether had been the chief anesthetic agent, usually being administered by the open drop method. The development of ether vaporizers and the discovery of the anesthetic properties of ethylene and cyclopropane favored the development of closed, or semiclosed systems for the administration of inhalation anesthesia. It was shown as early as 1923 that carbon dioxide excreted by the patient

could be readily eliminated by chemical absorbents. With this technique, the patient breathes an artificial atmosphere containing a supply of oxygen derived from an oxygen cylinder controlled by the anesthetist. The exhaled carbon dioxide is removed from the breathing circuit by passing it over soda lime or a similar absorbent material. Metered flows of anesthetic gases or volatile vapors are administered to produce the desired depth of anesthesia. The rebreathing technique is desirable in administering flammable anesthetic gases because it prevents the escape into the atmosphere of flammable substances in substantial quantities. It is difficult to estimate the exact concentrations of anesthetic agents and the percentage of oxygen in a completely closed system, since the metabolic uptake of oxygen varies from patient to patient. For this reason, semiclosed systems are more frequently employed, thus permitting some of the mixture to overflow into the atmosphere.

In terms of the hazardous development of explosive mixtures, the significance of mixing pure oxygen with cyclopropane in the rebreathing circuit can be seen by studying a table of the flammable limits of anesthetic agents in air and oxygen. Cyclopropane in air is flammable in a range of 2.4 to 10.4 percent. The range in an oxygen mixture is from 1.8 percent to 60 percent. For ethylene the ranges are 3.1 to 32 percent in air, and 2.9 to 79.9 percent in oxygen. When sufficient oxygen is provided to maintain the patient's life, and anesthetic concentrates of cyclopropane or ethylene are present, the resulting mixture usually falls within the flammable range.

As a means of reducing explosive hazards, anesthesiologists have suggested that cyclopropane-oxygen mixtures be diluted by an inert gas, such as helium. Theoretically this plan is feasible. In practice, however, it means that a semiclosed or overflow system must be employed and that extra precautions must be taken to provide the patient with an adequate supply of oxygen always in excess of 21 percent.

For the past 25 years, since the first recorded explosion of cyclopropane in anesthesia, the search has continued for an anesthetic which would possess all the favorable characteristics of cyclopropane and ethyl ether, but without their attendant hazards. A number of intravenous anesthetic agents, capable of producing unconsciousness and sleep but not possessing true analgesic properties, have been developed. These are satisfactory for limited use but they do not meet all the criteria. Recently, an essentially nonflammable gas, generically known as halothane, has been introduced into the field of anesthesiology. Halothane has, to a great degree, replaced ethyl ether and to a lesser extent cyclopropane. There are a number of clinical situations, however, in which halothane may be contraindicated and in which cyclopropane or ethyl ether may have advantages. In the future, there is room for optimism that a complement of noninflammable anesthetic agents may replace flammable materials and thereby relieve hospitals of the expense of administrative problems of preventing anesthetic explosions.

The exact nature of the explosion hazard is not well understood. The key to measuring the hazard lies in the fact that the anesthetic range of the gas-oxygen mixture is very nearly synonymous with the explosive range. In addition, flammable anesthetic gases diffuse rapidly in the atmosphere. Thus, except for the exposure of the patient to the concentration of explosive mixture in his airway, the likelihood of an explosion exists only within inches of where the gas-oxygen mixture may escape from the closed rebreathing system. Accidents do occur when a jet of escaping mixture is ignited by a static spark. More frequently, fatal accidents involve explosion entirely within the rebreathing cycle, including the patient's airway and the anesthesia machine. The explosions are often very violent.

Even though the range of explosive mixtures is limited, electrical installations in the operating room wall should be explosionproof to a height of 5 feet. This requirement is linked to the mobility of the average surgical table and the fact that a jet of escaping gas could be projected to a piece of electrical equipment at the wall if the table were located near the wall. The hazard would also be present if the table were so located that the anesthetist sat with his back to the wall with the anesthesia machine immediately on either hand.

The physical extent of the explosive range of anesthetic mixtures was reaffirmed by two research projects sponsored by the Public Health Service and completed in 1957. One of these investigations was made by the Division of Explosives Technology, U.S. Bureau of Mines, while the other was carried out by F. A. Van Atta, Ph. D., specialist on environmental safety for the United Auto

Workers and for many years a member of the NFPA Committee on Hospitals. The Public Health Service summarized the reports as follows:

> In respect to ether vapor, the Bureau of Mines concludes that the sudden spillage of 150 cc or slow spillage of 350 cc of ether causes flammable mixtures in the vicinity of the liquid which can be explosive . . . the spillage of ether in spaces or receptacles such as sinks, cabinets or urns may produce sufficient flammable mixtures to creat serious explosion hazard.
>
> From a review of these two reports, it is concluded that for any quantities of ether normally used, or spilled from open container at one time in an anesthetizing location, flammable concentrations of ether vapor are not expected to extend more than about 2½ to 3 inches vertically from the point of use, or from any surface such as the floor.[1]

Dr. Van Atta reported the limit of a horizontal spread from a center of spillage of a quarter-pound of ether poured from 1 inch above the floor to be about 2 feet 6 inches. The Bureau of Mines reported limits of horizontal spreads of about 2 feet and 4 feet respectively for 150 cc (0.25 pounds) and for 350 cc (0.61 pounds) of ether poured from nine-sixteenth inches above the floor.

Dr. Van Atta concluded from rough calculations and measurements with the explosimeter that the dangerous area around an operation is in the gas machines, immediately around them, and immediately around the mask and tube.

These findings, however, are no invitation to complacency.[2] While there are no dependable figures comparing the number of explosions and patient deaths to the number of anesthesia administrations, these deaths continue to occur. However, widespread adoption of preventive measures has substantially reduced anesthesia explosions.

Since the advantages of cyclopropane are so substantial that it will probably be included in the complement of anesthesia materials until an equally satisfactory nonflammable gas is discovered, and because oxygen must be used with every gaseous anesthetic to preserve life, the only remaining avenue for explosion protection is removal of ignition sources.

NATIONAL FIRE PROTECTION STANDARD NO. 56

Code for the Use of Flammable Anesthetics (Recommended Safe Practice for Hospital Operating Rooms), the NFPA Standard No. 56, recognizes two kinds of hazardous spaces in terms of flammable anesthetic danger. One is the area in which such materials are stored; the other is the anesthetizing location in which they are used. Potentially, any space used for long-term storage of flammable anesthetic containers is subject to explosions of great force. On the other hand, an explosion that takes place during surgery is more likely to claim a patient's life but has less potential for structural or widespread fire damage.

Because storage locations may involve substantial accumulations of gas if gross leaks exist over a long period of time, positive ventilation is mandatory. The original Standard called for gravity ventilation of storage locations since electrically operated exhaust fans might be carelessly turned off for long periods of time. It was recommended that the gravity exhaust system be designed to furnish two air changes per hour. The current revision of Standard No. 56 permits either gravity or forced ventilation at the rate of eight air changes per hour.

Because of the small amounts of anesthetic gas involved in the anesthetizing location, Standard No. 56 does not specifically require, but does suggest, mechanical ventilation for the operating rooms. However, since static dissipation is substantially increased by adequate humidity in the air the Standard recommends maintenance of relative humidity at not less than 50 percent.

Sources of Ignition

Hot Body and Open Flame. Possible sources of ignition may be catalogued in three classifications. The first of these is the hot body or open flame. While there is no problem in prohibiting open flames in anesthetizing locations, the question of hot bodies raises serious problems of medical decision. For example, cautery is frequently required during surgery and the instrument used is essentially a hot body. Frequently, as in a tonsillectomy, it is necessary to introduce a cautery into the same general area in which flammable anesthetics are being used.

Standard No. 56 suggests the following regarding cautery:

> If cautery, endothermy, or other electrical equipment employing an open spark is to be used during an operation, flammable anesthetics shall not be used unless the patient's life would be jeopardized by the selection of other anesthetic agents in the combined judgment of the surgeon performing the operation and the anesthesiologist responsible for administration of the anesthetic . . . .
>
> Hospital administrative authorities shall take such steps as are necessary to impress upon personnel the additional risk involved in the use of cautery and endothermy during operations in which flammable anesthetics are used . . . .
>
> If cautery or endothermy must be used in an operation, hospital regulations shall require that the surgeon performing the operation and the anesthesiologist responsible for the administration of the anesthetic shall select a nonflammable anesthetic, except that cautery or endothermy may be used in the presence of flammable anesthetics if in the combined judgment of the surgeon and the anesthesiologist, failure to do so would jeopardize the patient's life, and they jointly accept responsibility for the deviation.

The further suggestion is that the patient be so draped that a barrier is provided against any escape of flammable mixture to the area in which cautery or endothermy is being applied.

Other and more complicated sources of ignition include electrical arcs and sparks which may ignite flammable mixtures and the insidious, unseen arcs of static electricity. The precautions for dealing with these sources are interrelated since electrical interconnections designed to prevent development of static charges also tend to increase possibilities of electrical shock.

Electrical Hazards. Again, entirely on the basis of the amount of gas likely to be present, the extent of the hazardous location differs substantially as it affects electrical wiring.

The storage location is a hazardous area throughout. All electrical wiring in this space must be of explosionproof design. Because storage locations tend to be relatively small rooms and explosionproof wiring materials are expensive, it is common to place the light switch outside the room, where it may be of standard rather than explosionproof design. Any lighting fixtures or electrical receptacles within the storage room, however, should conform to the provisions of Article 500 of the National Electrical Code and should be of explosionproof design and construction. Conduits serving such fixtures should be sealed in accordance with requirements of the same model code.

In anesthetizing locations the top of the hazardous zone is defined as a line 5 feet above the floor. There is no magic about the 5-foot level as such. It is an arbitrary location chosen by the NFPA Committee as being far enough away from any probable point of leak to be outside the zone of explosive mixture but low enough to permit the installation of electrical switches above the hazardous location so that they need not be explosionproof.

Unlike the 15- to 20-ampere sockets and receptacles used in residences, explosionproof switches and electrical receptables are not standardized. This is a nuisance for hospital users of this equipment, and particularly so when explosionproof receptacles installed below the 5-foot level do not match receptacles of the ordinary variety installed above the 5-foot line in the same room. Furthermore, there was initially no basic provision for receptacles allowed above the 5-foot level to insure their safe use over a hazardous location.

To meet this need, the Committee recommended specific dimensions for electrical plugs to be used on all electrical equipment in anesthetizing locations. A receptable of either explosionproof or ordinary type for use in anesthetizing locations should be of a configuration that will accept this plug design.

Protection Against Static Spark Ignitions. Most people go through their normal activities unaware of the extent to which they generate static electricity, except perhaps on very cold days when they create extremely high charges by walking on nylon or wool carpets. Cotton and unmodified rayon (regenerated cellulose) have less resistance to electrical currents than wool and synthetic fabrics. The latter have certainly been noted by many wearers to produce static charges. Such charges are frequently released to ground, causing a spark so tiny that it is usually unnoticed. Nevertheless, it has been demonstrated by the Bureau of Mines that such small sparks can ignite explosive mixtures.

Hospital administrators and architects have been faced with the problem of selecting a conductive floor that will retain its conductivity and

still meet standards of esthetics and maintenance. Numerous floors have been tried and some have been found inadequate for a variety of reasons.

At present, three general types of floors have the greatest acceptance. One of these is conductive mosaic tile, a durable hard floor sometimes laid in a conductive cement grout or in a thin mastic bed setting. Excellent results have been obtained with both types of settings, although there have been scattered reports of conductive grout settings losing their conductivity, probably because of improper mixing of the grout. On the other hand, at least one case can also be documented of a mechanical failure where the thin bed setting has been used. Such problems are cited not to discourage the use of any one type of conductive flooring but rather to indicate the need for judgment in determining the setting in which the tile is to be laid, close supervision during installation, and most important, frequent routine conductivity testing.

Resilient conductive floor types include conductive vinyl tile and linoleum. Excellent results have been obtained with both floors. One additional type of conductive floor lies between the hard and resilient and is comprised of a conductive latex as a binding material and marble chips as an aggregate, much in the same way as cement terrazzo is constituted. To date, these floors appear to have both durability and constancy of conductivity.

Conductive floors are required in all anesthetizing locations and all areas immediately serving these anesthetizing locations such as corridors and sterilizing rooms. In addition, the conductive floor is required in storage locations for flammable anesthetic agents but not in storage locations for oxygen and nitrous oxide.

Appendix A of Standard No. 56 suggests, relative to the dissipation of static electrical charges:

> In hazardous locations, a conductive floor serves as a convenient means of electrically connecting persons and objects together to prevent the accumulation of electrostatic charges. A resistance not exceeding 5 to 10 megohms between the objects or persons is generally sufficient to prevent dangerous voltages. The upper limit of 1,000,000 ohms * for the resistance of the floor has been chosen as meeting this requirement with a reasonable factor of safety and with reasonable provision for other resistances in the conductive path. A conductive floor need not be provided with a special grounding connection to prevent the accumulation of charges due to the motion of objects and persons resting on it. To be effective it is necessary only that it be conductive and that the persons and objects be electrically connected to it. Considerable conductivity to ground is generally obtained in the usual construction, often because of the proximity of grounded conduits and water pipes. This incidental conductivity to ground and the large area, and therefore capacitance of the floor, make any hazard due to the entry of persons or objects in the protected zone negligible, provided such persons and objects have proper conductivity to the floor.

Each individual entering the anesthetizing location should be connected to the conductive floor by some type of conductive footwear. There has been a wide swing toward the use of conductive bootees. The bootees have achieved popularity because they are confortable, connect by their soles to the skin of the wearer, and have some limiting effect on bacterial spread.

The surgical table is another vital part of the conductive chain. Contact between it and the conductive floor is maintained through conductive casters, while contact between table and patient is attained through a conductive strap placed over or around the arm, leg, or abdomen.

The anesthesia gas machine is another vital link in the conductive chain. It is still good practice for the anesthetist to maintain the conductive chain physically by contact between patient's skin and anesthesia machine. However, this is such a sensitive area in terms of anesthetic explosion that standard operating procedure provides for all parts of the anesthesia machine such as face mask, cushion, tubing, and casters to be conductive. It is also good operating procedure for the anesthetist to test all such equipment at least once a week and to pretest it thoroughly prior to its original use. Materials such as conductive rubber hose can lose conductivity on the shelf.

Chapter 25 of Standard No. 56 prescribes the method for testing conductive floors. Article No. 352 requires the conductive floor to be tested prior to first use and at least once a month thereafter.

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* In the "Code" portion of Standard No. 56.

A permanent record of the readings should be kept by the hospital.

Through the years, experience has shown that conductive floors can be insulated by improper maintenance such as inadequate rinsing away of soap scums or through buildup of insulating floor wax. While a good housekeeping program will eliminate practices that result in this type of conductivity loss, safety can be insured only by frequent checking with an ohmmeter.

Electrical Shock Hazards

With modern electrical distribution systems using a grounded return, the mild conductivity of the floor creates a shock hazard. This is the reason Standard No. 56 requires the floor to have a minimum resistance of 25,000 ohms. While this should be adequate protection against shock, it cannot be guaranteed as protection against every possibility of shock. Therefore, a second line of defense against electrical shock hazard introduced by the conductive floor is an ungrounded electrical system.

With ordinary grounded wiring a shock may be sustained by touching a grounded object and a live electrical conductor at the same time. When an electrical system is connected to a one-to-one insulated transformer, the circuit can no longer be completed by contact between a live conductor and a grounded object but requires contact with two conductors.

The ground indicator mentioned in Standard No. 56 in conjunction with the isolating transformer is included so that in the event of unintentional grounding of the circuit personnel working in the operating room will be aware of the increased hazard. The alarm is given by a red signal lamp and an audible warning when any one conductor of the system becomes grounded through a resistance, or a capacitive reactance, of any value up to 60,000 ohms. The ground-contact indicator is so arranged that a green signal lamp is conspicuously visible while the system is isolated from ground.

Use of Electrical Equipment

All electrical equipment intended for use or being used in an anesthetizing location should be approved for use in hazardous locations. While the word "approval" can be interpreted differently in different jurisdictions, it is more commonly interpreted as requiring Underwriters' Laboratories listing "for use in hazardous location." This approval means that Underwriters Laboratories have thoroughly checked the equipment in accordance with their standards. Surgical equipment approved for use in hazardous locations may be used in atmospheres containing a flammable mixture of ethyl ether vapors, and may sustain an explosion within the equipment without the flame being propagated to the atmosphere surrounding it.

The equipment should also meet certain criteria set forth in Standard No. 56, such as the provision for continuous flexible cords without switches from appliances to attachment plug and of a type designated for hard use. The flexible cord should contain one extra insulated conductor to form a grounding connection between the ground terminal of the plug and the metal motor frames or other exposed metal portions of the appliance. It should be of sufficient length to reach any position in which the portable device is to be used, and the attachment plug should be a type that can be inserted only in an approved fixed receptacle. The provision that no switch be inserted in this cord carries an exception for foot treadle operated controllers. These are permitted if appended to the appliance in an "approved" manner or if they are integral with the supply cord and equipped with a connector containing an anesthetizing location receptacle for use in Class 1—Group C atmospheres. In short, the foot treadle should be either a permanent part of the cord or contain an approved anesthetizing location receptacle into which the appliance may be plugged.

When the foregoing criteria for grounding the frame of each piece of equipment is considered, together with the provisions for conductive floors, it is obvious that a substantial electrical hazard could develop unless the ungrounded circuit with ground detector is used. The detector quickly warns operating room personnel if defective equipment is plugged into the system.

All these requirements are supported by maintenance provisions. For example, Article 342 of Standard No. 56 specifies that hospital administrative authorities should ascertain that electrical maintenance personnel are completely familiar with the function and proper operation of ungrounded electrical circuits. The significance of signal lamps and audible alarms should be ex-

plained to all affected personnel. All circuits in panel boxes should be clearly labeled to distinguish between grounded and ungrounded, emergency and normal circuits. Particularly, the proper function of the ground indicator circuit should be tested at intervals of one week in the manner prescribed by the Standard and a permanent record kept of the results of these tests.

Similarly, hospital administration should prohibit the use of portable electrical equipment and appliances that are unsuitable for use in hazardous locations while anesthetizing locations are occupied by patients, or when anesthesia equipment is in operation. Professional staff members should be required to obtain approval for any special equipment they wish to introduce into anesthetizing locations. Standard No. 56 leans heavily on administrative vigilance because of a strong belief throughout the NFPA Committee that even the safest construction cannot prevent accidents unless all employees are thoroughly oriented and all equipment is regularly tested and properly maintained by technicians familiar with the reasons behind their various activities.

Individual Considerations

In setting forth the various administrative responsibilities, the Standard does not urge surgeons to follow blindly the recommendations without regard for other, and perhaps overriding, considerations. Article 314 plainly states:

> This Code for the Use of Flammable Anesthetics is intended to provide protection against anesthesia explosion hazards without unduly limiting the activities of the surgeon. This principle, without minimizing anesthesia explosion hazards, recognizes that the surgeon shall be guided by all of the hazards of life that are inherent in surgical procedures.

This is not an invitation for the surgeon to carelessly disregard anesthesia explosion safety. It, however, does recognize that, faced with two or more conflicting indications bearing on the safety of the surgical patient, the surgeon must be able to elect the least hazardous course even though that choice may involve some calculated risk. The conservative surgeon or anesthesiologist will, when there is sufficient advance notice, arrive at his judgment in consultation with other qualified physicians and record the consultation. When no time is available for consultation he should at least record the basis of his judgment. Failure to follow such a course might open the physician, and very possibly the hospital, to charges of negligence if any injurious or fatal explosion should ensue.

Questions frequently arise as to the extent of the hazardous area outside the actual operating room such as a preoperative induction room in which flammable anesthetic gases are administered. Obviously, such a location is an anesthetizing location whether or not it is the site of surgery. On the other hand, locations such as emergency treatment and cystoscopy rooms, plainly intended to be the site of surgery, may not have been intended by the hospital to be used for the administration of flammable anesthetic gases. (See fig. 17.)

Figure 17. **Calibration of heart-lung machine should be carried out in properly protected areas.**

In a note following the limitation of the "hazardous location" to the area below the 5-foot level, Standard No. 56 says:

> An adjoining area connected by a closable doorway, such as a corridor, substerilizing room or X-ray control room, where it is not intended to store or administer flammable anesthetics, is not considered a hazardous lo-

cation. Such a location may be wired in accordance with the National Electrical Code for general wiring for ordinary locations. . . . Recovery rooms are not considered as anesthetizing locations unless specifically intended for the induction of anesthesia.

The development of the nonflammable halothanes which have come into increasing acceptance in recent years raises questions as to what course a hospital might follow if it decided to prohibit the use of flammable anesthetic agents. On this subject, appendix A (sec. A3172) states:

> The Committee has been informed of a number of instances of hospitals attempting to avoid compliance with this Code by prohibiting the use of flammable anesthetics throughout the hospital premises. While it is obviously within the discretion of any hospital corporation to forbid the use of flammable anesthetics and while this Code will not apply in a hospital where this is done, it is the feeling of the Committee that in the present state of art it would be a very unwise move. The noninflammable anesthetics now available are sufficiently new (December 1961) as to be considered almost experimental, and many surgeons and anesthesiologists would consider such a prohibition as an unwarranted interference with their freedom of choice or with their judgment in taking the most effective care of their patients.

Appendix A also suggests a means whereby areas in which the use of flammable anesthetics are prohibited, usually with the acquiescence of the medical staff, may be exempted from the provisions of the Standard.

With the increasing acceptance and development of nonflammable anesthetic agents, many hospitals may find it safe and convenient to discontinue some of the safeguards, such as explosionproof wiring and conductive floors, recommended in Standard No. 56. Certainly, such action should be taken only upon the advice and agreement of the hospital anesthesiologist and with concurrence of the medical staff.

Whether local enforcement agencies will accept such a procedure will be a matter of individual decision on the part of these agencies. It is nevertheless hoped that any hospitals which abandon the use of flammable anesthetics but already have isolated, ungrounded electrical systems in their operating rooms will continue to use these systems if conductive flooring has been removed or covered. The ungrounded systems provide a real measure of protection for personnel against electrical shock and a prompt warning of faults in the wiring within surgical equipment. It is vital that as long as conductive flooring remains in operating rooms the ungrounded system be kept in operation.

Originally, the entire electrical installation in the operating room was to be served by the ungrounded circuit. One design problem with the ground detector system is that it cannot distinguish between the grounding effect caused by a fault and a grounding effect due to insulation leakage or capacitance between conductors and grounded objects such as the conduits in which they are carried. A few years ago electrical engineers complained that they were having difficulty maintaining the ground detector systems when fluorescent lights were installed for general operating room lighting. Similar problems had been encountered with X-ray installations in operating rooms. Accordingly, normal grounded circuits supplying fixed lighting above the hazardous locations, other than surgical lighting fixtures, were excepted from the specifications for ungrounded circuits in Standard No. 56. Under certain conditions, X-ray equipment was also excepted from the requirement. The exception was contingent on wiring of grounded and ungrounded circuits being placed in separate raceways with none of the fixtures or X-ray equipment (except the enclosed X-ray tube and metal-enclosed high voltage leads to it) located less than 8 feet above the floor. Switches controlling these grounded circuits were specified to be outside the anesthetizing location or to be remote control switches operating an ungrounded secondary circuit.

PIPING OF MEDICAL GASES

NFPA Standard No. 565 deals with the piping of medical gases. It prohibits the piping of all flammable gases in hospitals and prescribes precautions to be followed in the piping of other medical gases, particularly oxygen and nitrous oxide. The Standard begins with a description of the installation method for a source of supply. This source may be a battery of manifold com-

pressed gas cylinders inside the hospital or some type of bulk supply installed outside.

Standard No. 565 also describes necessary warning systems to give alarm when the system has switched from a main to a reserve supply or from one main supply to an alternate. Alarms are also recommended to register low line pressure and, under certain conditions, when the emergency reserve supply drops to a dangerous level.

Chapter 4 of the Standard establishes criteria for pipelines, their fittings, protection, and identification. It recommends appropriate labeling with the name of the gas on the piping at intervals of not more than 20 feet and at least once in each room and storage area traversed by the pipeline. It also specifies where shutoff valves are necessary, essentially at the location where each riser and distant than one-half the height of the adjacent thetizing locations should be outside the anesthetizing location unless an alternative specified in the Standard is followed. Each station outlet for oxygen or nitrous oxide service should be equipped with an approved quick-coupler valve of a noninterchangeable type. The quick-coupler should be so designed and installed that it may be removed from the line without shutting the branch line valve. This is accomplished with the equivalent of a check valve which operates when the quick-coupler valve is removed.

BULK OXYGEN SYSTEMS

Bulk oxygen systems are covered in NFPA Standard No. 566, "Standard for Bulk Oxygen Systems at Consumer Site." One provision of the Standard deals with the distance to be established between any bulk oxygen system and possible explosion sites. The Standard recommends that bulk oxygen storage containers be at least 50 feet from any combustible structure and 25 feet from any structure with fire resistive walls or sprinklered buildings of other construction, but not less distant than one-half the height of the adjacent side wall of the structure. Containers should be at least 5 feet from any fire resistive structure, provided that any part of the bulk oxygen storage equipment is at least 10 feet from any opening in the adjacent wall. In addition, there are various provisions with respect to distances between bulk oxygen systems and various combustible inflammable materials. The Standard also specifies that the storage container be at least 50 feet from areas occupied by nonambulatory patients.

NONINTERCHANGEABILITY OF CONNECTIONS

Standard No. 56 recognizes use of the Pin-Index Safety Systems for assuring that the only gas tank on an anesthetizing machine that can be connected to the yoke for a specific type of gas is that containing the gas corresponding to the Pin-Index drilling on the face of the yoke. This system has been successful in reducing the possibilities for misadministration of anesthetic gases. A classic example of the administration of nitrous oxide instead of oxygen occurred in a new hospital the first time the piping system was used. The wrong gas was administered in the first two operations performed in the operating room with the subsequent death of both patients.

This possibility should be a warning to every administrator and anesthetist to assume a personal responsibility for checking out all new equipment to insure that misadministration of gases is prevented and that whenever any gas administration equipment is serviced, it is done only by completely qualified and responsible service personnel. The work should be cross-checked by a qualified hospital representative who is immediately responsible to the administrator. While the Pin-Index system is helping protect anesthesia machines, the growing tendency to install medical gas piping in hospitals opens the way for other types of gas administration accidents.

There are many anesthesiologists who insist that gas administered for anesthesia come only from tanks attached to the anesthesia machine. Certainly this is a safe course and one that keeps gas completely under the control of the anesthesiologist. It is questionable that the savings from piping anesthesia gas to operating rooms in many hospitals are so substantial that they could not be sacrificed in favor of life safety. In large installations there may be substantial financial savings from oxygen piping alone. If only oxygen is to be piped to anesthetizing locations, the hazard lies between source of supply and anesthetizing machine. Beyond the view of the anesthesiologist, some unauthorized person may close a valve. The

answer to this possibility is for the anesthetist to keep a spare cylinder of oxyen on the anesthesia machine, as many already do, for insurance against such tampering.

None of the foregoing should discourage the oxygen piping throughout patient room areas in general hospitals which is universally practiced today. Systems for piping suction to patient areas also deserve consideration. Such systems usually require tandem pumps and tanks wired for alternate operation and connected to the protected continuity electrical system.

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